Volume 30 NOVEMBER, 1956 Number 6

JOURNAL OF PALEONTOLOGY

UNIVERSITY OF MICHIGAN
JAN 1 1957
MUSEUMS LIBRARY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation of* The American Association of Petroleum Geologists *and* The Geological Society of America

CONTENTS

Pennsylvanian fusulinids of eastern Nevada ..... *G. J. Verville, M. L. Thompson,* and *D. H. Lokke* 1277

Upper Miocene Foraminifera and fish from the Los Angeles area, California ..... *Richard L. Pierce* 1288

Fern Glen (Mississippian) Ostracoda ..... *Dorothy Jung Echols* and *John J. Gouty* 1315

Taxonomy, nomenclature, orientation, and stratigraphic evaluation of conodonts ..... *Klaus J. Müller* 1324

Revisions in nomenclature and new species of Cambro-Ordovician trilobites from the Marathon uplift, West Texas ..... *James Lee Wilson* 1341

The index value of Silurian Foraminifera and some new forms from wells in Kansas ..... *Halsey W. Miller, Jr.* 1350

Addendum to a bibliography of the family Fusulinidae ..... *Donald F. Toomey* 1360

PALEONTOLOGICAL NOTES 1367

REVIEWS 1376

NOTICE 1382

SOCIETY RECORDS AND ACTIVITIES 1383

INDEX 1387

EDITORS

For The Paleontological Society: WILLIAM R. EVITT, The Carter Oil Co., P. O. Box 801, Tulsa, Oklahoma.

For The Society of Economic Paleontologists and Mineralogists: W. M. FURNISH, Department of Geology, State University of Iowa, Iowa City, Iowa.

The JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

Communications in regard to manuscripts or purely editorial matters should be sent to the editors at addresses above.

Authors should consult a recent issue of the JOURNAL for appropriate style and form before preparing their manuscripts. A brief, informative abstract should accompany every article except nomenclatural notes only one or two paragraphs long in which the title is sufficient to serve as an abstract of the contents. All new taxonomic names proposed in a paper should appear in the abstract.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the maximum size of 5¼×8¼ inches, exclusive of margins and heading. Printed numerals of standard size and form may be obtained free from the editors. When requesting them state number of plates and dimensions of each plate. Text-figures should be designed for reproduction at either single column (2⅛ inches) or full page (5¼ inches) width, maximum height 7½ inches. Typewritten copy is not acceptable for text-figures.

OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending March 1957

President
ROBERT R. SHROCK, Cambridge, Mass.

Vice-President
R. V. HOLLINGSWORTH, Midland, Texas

First Past President
F. J. PETTIJOHN, Baltimore, Md.

Secretary-Treasurer
S. P. ELLISON, JR., Austin, Texas

Editors
W. M. FURNISH, Iowa City, Iowa
for paleontology
JACK L. HOUGH, Urbana, Ill.
for mineralogy

THE PALEONTOLOGICAL SOCIETY

For the year ending November 1957

President
G. A. COOPER, Washington, D. C.

Vice-President
F. M. SWARTZ, State College, Penn.

Secretary
HARRY B. WHITTINGTON, Cambridge, Mass.

Treasurer
CLAUDE C. ALBRITTON, Dallas, Texas

Editors
ERWIN C. STUMM, Ann Arbor, Mich.
ROBERT V. KESLING, Ann Arbor, Mich.

Past Presidents
HENRYK B. STENZEL, Houston, Texas
A. SCOTT WARTHIN, JR., Poughkeepsie, N. Y.
HARRY S. LADD, Washington, D. C.

Entered as second-class matter at the Post Office at Tulsa 1, Oklahoma, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R, authorized April 3, 1935.

Additional entry as second-class matter at the Post Office at Menasha, Wisconsin.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 30 NOVEMBER, 1956 NUMBER 6

PENNSYLVANIAN FUSULINIDS OF EASTERN NEVADA

G. J. VERVILLE, M. L. THOMPSON, AND D. H. LOKKE

Stanolind Oil & Gas Company, Tulsa, and University of Kansas, Lawrence

ABSTRACT—The new fusulinid genus *Bartramella* and the new species *Fusulinella nevadensis, F. alta, Fusulina weintzi,* and *Bartramella bartrami* are described from the Pennsylvanian Ely limestone in the Cherry Creek Mountains, White Pine County of eastern Nevada. *F. weintzi* is an advanced form of the genus *Fusulina,* and its association with typical species of *Fusulinella* extends the range of the latter genus considerably higher than formerly known in America. The new genus *Bartramella* has not been observed from central United States.

GENERAL CONSIDERATIONS

THE Pennsylvanian rocks of eastern Nevada contain large faunas of fusulinids, some generic groups of which have associations and obvious ranges somewhat different from their ranges in central United States. The major elements of fusulinids evolved throughout the world in the same relative order, and the first appearances of biologic groups doubtless coincide closely. However, in many areas some biologic units maintained themselves longer and ranged higher in the stratigraphic section. The large Pennsylvanian faunas of Nevada probably have been affected to some degree by the mingling of fusulinids from different provinces as a result of marine invasions from the west coastal region, from the south Pacific region, from the north Pacific region, and from regions to the southeast through Arizona and New Mexico from parts of Texas and northern Mexico. In contrast to these numerous invasions and regional migrations, the middle and eastern areas of America probably had only a limited invasion route from the south and west through Texas and Oklahoma.

In the middle and eastern American regions the fusulinid faunal zones of the Pennsylvanian are based on the restricted range or dominance of certain fusulinid genera. In ascending order they are defined as the Zone of *Millerella*, Zone of *Profusulinella*, Zone of *Fusulinella*, Zone of *Fusulina*, and Zone of *Triticites* (Thompson, 1948). In only the second and fourth of these is the genus restricted to the zone which bears its name, and in all others the zone genus actually ranges up into the following faunal element. More precisely, *Millerella* has a range to the top of the Pennsylvanian and far beyond the top of the "Zone." This zone is defined on the dominance of *Millerella* without other common fusulinids. The Zone of *Profusulinella* corresponds to the limits of the genus, and so far as known, represents the complete evolutionary span of the genus. The Zone of *Fusulinella* is defined as starting with the first appearance of the genus and extends

up into faunas containing the first major but primitive elements of the genus *Fusulina*. However, *Fusulinella* is known to range up into the lower part of the stratigraphic section which contains abundant primitive *Fusulina*. *Fusulina* started, and doubtless developed from *Fusulinella*, near basal Desmoinesian time and ranged into lower Missourian time (Bethany Falls limestone—Thompson, et al.; 1956). The genus is known to have a stratigraphic range in Europe into rocks as young if not younger than the Bethany Falls. The Zone of *Triticites* is defined as including the range of the genus *Triticites* from near the beginning of the Missourian into the lower Wolfcampian. However, this genus occurs in Wolfcampian rocks with several other genera which are restricted to Permian rocks, and their ranges form the bases for defining other fusulinid zones, such as the Zone of *Schwagerina*, the Zone of *Pseudoschwagerina*, and the Zone of *Paraschwagerina*. The Zone of *Triticites* is commonly restricted to the upper Pennsylvanian where *Triticites* dominates the faunas.

The fauna we are studying from eastern Nevada contains *Fusulinella* and an advanced *Fusulina*. This association has not been observed previously in America. The evolutionary aspects of this *Fusulina*, *F. weintzi*, n. sp., would indicate a correlation with middle Desmoinesian rocks from Iowa to New Mexico, and the forms of *Fusulinella* associated with it are typical of the genus.

Associated with the *Fusulina* and the *Fusulinella* species are very abundant specimens of a new genus described below as *Bartramella*, with *B. bartrami*, n. sp., as genotype. The position of *Bartramella* in the evolutionary sequence of fusulinids is not understood, but it possibly developed from an Asiatic group.

The fusulinids described in this paper were collected from the Ely limestone in the Cherry Creek Mountains in sections 5 and 8, T. 25 N., R. 63 E., White Pine County, Nevada. The section from which the collections were made was measured along the crest of the Cherry Creek Range. The lower collection (N-567-54) was made from a cherty limestone seven feet thick about 2,070 feet vertically above the base of the Ely limestone, and the upper collections (N-571-54, N-572-54) were made from a limestone 38 feet thick approximately 3,450 feet vertically above the base of the Ely limestone. The two limestones mentioned above probably are of about the same age and are separated vertically due to faulting. As the Desmoinesian beds are repeated several times by faulting, the vertical positions of the collections at this place do not necessarily represent true stratigraphic positions within the Ely limestone. The fusulinids described are present in several other fault-blocks in the region; however, the three collections used contain the best preserved specimens.

We wish to express our sincere thanks to the Stanolind Oil and Gas Company for permission to publish on these valuable collections. Special thanks are given for financial assistance from the General Research Fund of the University of Kansas and to Dr. M. K. Elias for Russian translations.

SYSTEMATIC PALEONTOLOGY

Genus BARTRAMELLA V., T. & L., n. gen.
Type species: *Bartramella bartrami*, n. sp.

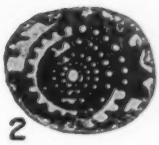
The new genus *Bartramella* is here established for a new fusulinid discovered in rocks of Desmoinesian age of the Ely limestone in the Cherry Creek Mountains, White Pine County, Nevada, named *B.*

EXPLANATION OF PLATE 133

All illustrations on this plate are unretouched photographs, and all are magnified ×20.

FIG. *1–13—Bartramella bartrami*, n. sp. *1*, Axial section of the holotype; *2,3*, sagittal sections of paratypes; and *4–8*, axial sections of paratypes. Fig. *1–8* are of specimens 1, 8, 7, 6, 4, 2, 3, and 5, respectively, from N-572-54. *9–11*, Axial sections and *12,13*, sagittal sections, from N-571-54.
14–18—Bartramella bartrami?, n. sp. *14,15*, Sagittal sections; *16–18*, axial sections, all from N-567-54, referred with question to this species.

1

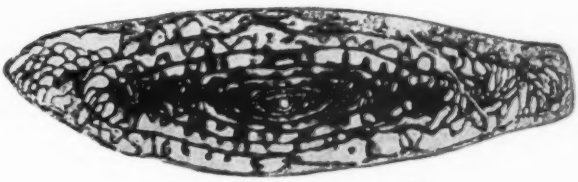

2

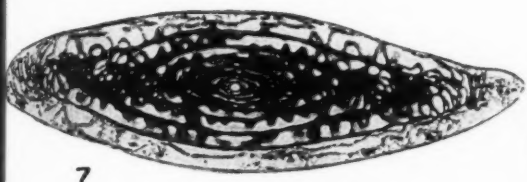
3

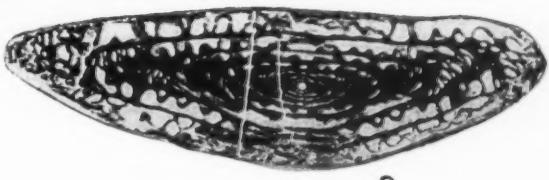
4

5

9


6

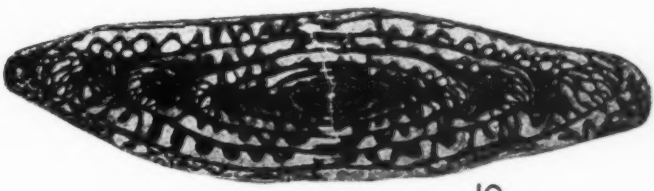

7

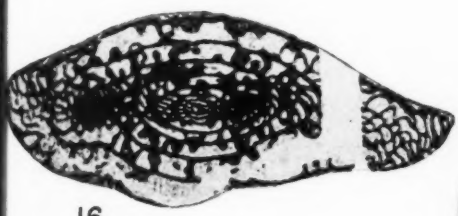

8

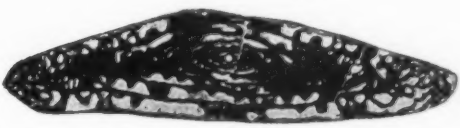
14

12

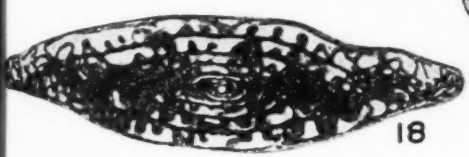
15

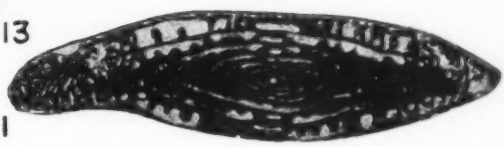

10

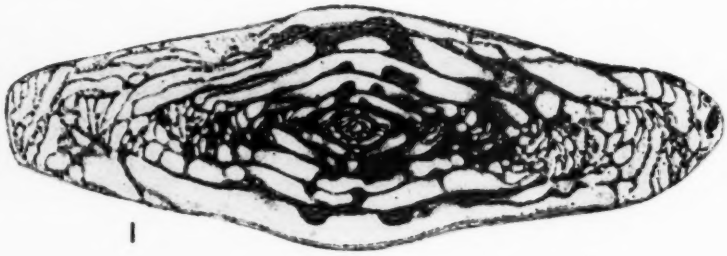

16


17

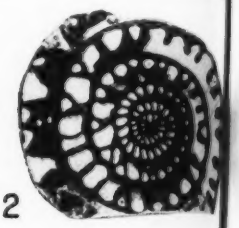
13


18


11

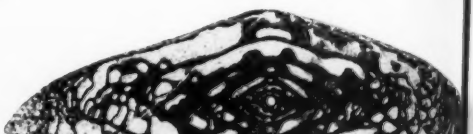


1



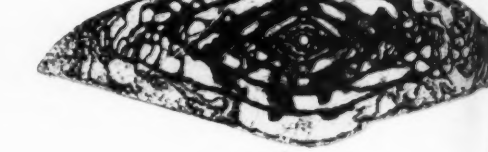
2

3

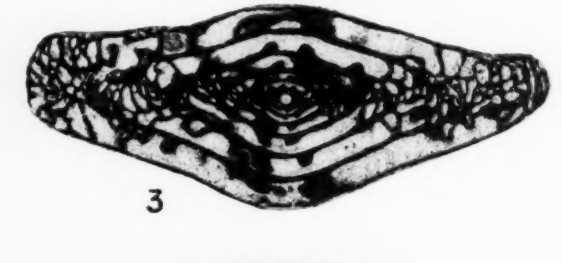


4

5

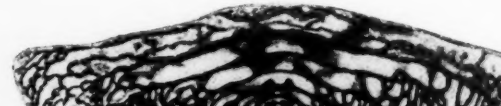


6



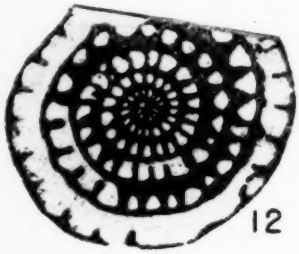
7

10

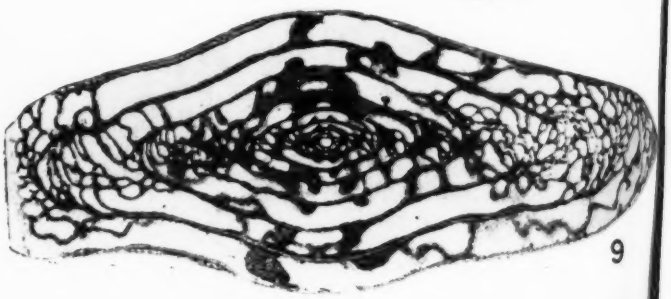


8

11



12



9

bartrami below. Its shells are elongate subcylindrical to subfusiform in shape; with extended to sharply pointed polar ends, curving to irregular axis of coiling, and irregular to slightly concave or convex lateral slopes. The genotype, and only known species, has seven to eight volutions at maturity, is 3.5 to 4.3 mm. long, and is 1.0 to 1.2 mm. wide. The shell has an elongate axis and pointed polar ends throughout growth and changes from a form ratio of about 1.7 in the first volution to about 4.0 at maturity. The expansion of the shell is slow but about uniform. The spirotheca is thin and composed of the tectum and a lower thicker layer which appears distinct only from the fifth or sixth volutions to maturity. Alveoli structures have not been distinguished, and the lower layer seems closely similar to the upper tectum part of the spirotheca except that perforations are more evident in the lower part. The septa are composed of a pycnotheca which can be distinguished only in outer volutions. Chambers are short throughout the shell, and the number of septa range from about 8 to 12 in the first volution to 27 in the seventh volution. Septal fluting is very narrow throughout the length of the shell and extends up the septa to the top of the chambers throughout the shell, except for the very central region where closed chamberlets have not been observed above the tunnel. The tunnel is low and broad, and its path is only slightly irregular. Chomata occur throughout all except the last few chambers, and they are high, with steep tunnel sides and low lateral surfaces. Axial fillings are very heavy in the first five to six volutions where they completely fill the chambers in the polar ends and extend to the edges of the chomata with gradually decreasing thickness. In outer volutions, however, the axial fillings only partly fill the chambers.

Remarks.—The new genus *Bartramella* is small and resembles in some respects *Boultonia* Lee and the group of fusulinids recently included by Skinner & Wilde (1954) in the subfamily Boultoniinae. However, it has a shell that is symmetrical in its coiling throughout growth and does not have an asymmetrical early stage as is found in all Boultoniinae. Furthermore, internal structural features of *Bartramella* are different from those of members of that subfamily, such as wall structure, chomata, septal fluting, etc.

The genus *Bartramella* shows a resemblance to several other fusulinid genera, such as *Akiyoshiella* Toriyama, 1953, *Verella* Dalmatskaia, 1951, and perhaps *Eofusulina* Rauser-Cernoussova, 1949. Some of the major points of difference with *Akiyoshiella* are the minute size of *Bartramella*, its more tightly coiled shell, different wall structure, difference in septal fluting, and its more uniformly fusiform and planispiral shell throughout growth.

The relationship of *Bartramella* to the genus reported as *Eofusulina* Rauser-Cernoussova is not understood by us. We have not seen the original description of *Eofusulina* and do not know its genotype species. Dalmatskaia (1951) reported *Fusulina triangula* Rauser-Cernoussova & Beljaev, 1936, as belonging to *Eofusulina* Rauser-Cernoussova. This species is small and has some features like those of *Bartramella*, including such things as heavy axial fillings, intensely fluted septa, and small size. The wall structure of *Eofusulina* is not known to us in detail. Further information is necessary before more detailed comparisons can be made.

The general septal fluting and axial fillings of *Bartramella* are closely similar to those of the genus *Dunbarinella*, but the spirotheca of *Bartramella* is considerably

---

EXPLANATION OF PLATE 134

All illustrations on this plate are unretouched photographs, and all are magnified ×20.

FIG. *1–12*—*Fusulinella alta*, n. sp. *1*, Axial section of the holotype; *2,12*, parallel sections of paratypes; *3,5–9*, axial sections of paratypes; *4*, axial section; *10*, sagittal section of a paratype; *11*, tangential section of a paratype. Fig. *1,3,5*, and *7* to *10* are of specimens 1, 5, 7, 4, 6, 2, and 3, respectively, from N-567-54. Fig. *4* is of a specimen from N-572-54 and all others are from N-567-54.

thinner and does not contain a distinct keriotheca as in *Dunbarinella*. There may be a closer relationship between *Bartramella* and *Dunbarinella* than we now understand.

This genus and its type species are named in honor of the late John G. Bartram.

Occurrence.—The genotype of *Bartramella*, and the only known species, is from the Ely limestone in the Cherry Creek Mountains of White Pine County, Nevada, where it is associated with *Fusulinella alta*, n. sp., and *F. nevadensis*, n. sp. (N-572-54, N-571-54). Abundant specimens probably of the same species are associated with *Fusulina weintzi*, n. sp. and with *Fusulinella alta* in our collection N-567-54.

BARTRAMELLA BARTRAMI V., T. & L., n. sp.
Pl. 133, fig. 1–18

The shell of *Bartramella bartrami*, n. sp., is small and elongate fusiform to subcylindrical in shape; with a straight to irregular or curving axis of coiling, irregular to low lateral slopes, and sharply pointed polar ends in the first six to seven volutions and more bluntly pointed polar ends in outer volutions. Also, in outer volutions of mature specimens the last few volutions are extended in the extreme polar ends somewhat irregularly. Larger shells of six and a half to seven and a half volutions are 3.5 to 4.3 mm. long and 1.0 to 1.2 mm. wide, giving form ratios of 3.4 to 4.2. Averages of the form ratios of the first to the seventh volution of six specimens are 1.7, 2.4, 2.8, 3.0, 3.2, 3.4, and 3.6, respectively.

The proloculus is minute in size and spherical in shape, measuring 76 to 100 microns in outside diameter and averaging 87 microns for eight specimens. The shell expands slowly throughout all volutions. Averages of the heights of the chambers above the tunnel in the first to the seventh volution of eight specimens are 29, 37, 61, 72, 82, 118, and 144 microns, respectively. The chambers are lowest above the tunnel and they increase very slowly poleward and become highest in the polar ends.

The spirotheca is thin throughout the shell and is composed of the tectum and a lower layer with no recognizable alveoli but with a porous structure. It is not sharply set off from the tectum. Averages of the thickness of the spirotheca in the fourth to the seventh volution of six specimens are 11, 16, 22, and 25 microns, respectively. The proloculus wall and the spirotheca of the first four to five volutions are too thin to measure accurately.

The septa are very thin and are composed of a thin pycnotheca in outer volutions, but its structure in inner volutions can not be distinguished. They are rather narrowly and highly fluted in the polar third of the shell but are most distinctly fluted in their lower half in the central third of the shell. Closed chamberlets do not seem to extend across the top of the tunnel, although the fluting reaches the tops of the chambers throughout the length of the shell. Averages of the septal counts in the first to the sixth volution of two specimens are 8, 14, 17, 18, 20, and 23, respectively.

The tunnel is low and wide in outer volutions but is very narrow in the inner five volutions. It is about half as high as the chambers in outer volutions. Averages of the tunnel angles in the third to the seventh volution in six specimens are 23, 22, 29, 36, and 43 degrees, respectively. The chomata have steep tunnel sides and low lateral slopes and occur thoughout the shell, except for the last few chambers. They extend up the septa to the top of the chambers so as to leave a small lateral opening and extend poleward in the inner five volutions to join with the axial fillings. Axial fillings completely fill the chambers in the polar zones in the inner five to six volutions and extend with gradually decreasing thickness to the edges of the chomata. In outer volutions of mature specimens the axial fillings spread toward the tunnel along the septa.

Remarks.—*Bartramella bartrami* is the only known species of the genus and specific comparisons seem unnecessary at this time.

Occurrence.—*Bartramella bartrami* is abundant in all three of our samples from the Cherry Creek Mountains in White Pine County, Nevada. However, the above description is based on specimens from collection N-572-54 which includes the holotype and paratype specimens. Abundant specimens also occur in N-571-54, and specimens referred with question to this species are common in sample N-567-54. It is associated with *Fusulina weintzi* and *Fusulinella alta*

Measurements of *Bartramella bartrami*, n. sp. (N-572-54), in millimeters

Specimen	L.	W.	Ratio	No. Vol.	Diam. of prol.	Height of volutions							Form ratio of volutions						
						1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	4.3	1.2	3.6	7	.096	.031	.049	.071	.072	.105	.130	.144	1.5	2.2	2.5	2.6	2.6	3.4	3.6
2	3.8	1.1	3.4	7	.087	.027	.037	.079	.067	.106	.118	—	1.9	2.8	3.1	3.3	3.3	3.2	3.4
3	3.5	1.0	3.5	7½	.076	.025	.030	.048	.068	.074	.101	.134	1.4	2.1	2.2	2.4	2.5	3.0	3.3
4	4.3	1.1	3.9	6½	.078	.038	.043	.070	.096	.125	.151	—	1.9	2.5	2.6	3.0	3.8	3.7	—
5	4.0	1.1	3.6	7½	.078	.019	.024	.037	.053	.071	.114	.154	1.4	1.8	3.0	3.4	3.6	3.8	3.7
6	4.2	1.0	4.2	7	.088	.022	.021	.041	.053	.079	.106	.144	2.3	2.9	3.1	3.4	3.4	3.4	4.2
7	—	1.1	—	7	.090	.035	.042	.054	.072	.082	.106	—	—	—	—	—	—	—	—
8	—	1.0	—	5½	.100	.038	.053	.085	.092	—	—	—	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count							Tunnel angle (degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	—	—	.010	.014	.021	.026	—	—	—	—	—	—	—	—	—	26	23	28	32	—
2	—	—	—	.011	.015	—	—	—	—	—	—	—	—	—	—	—	21	18	26	31	—
3	—	—	—	.011	.019	.024	.022	—	—	—	—	—	—	—	—	—	—	17	21	32	39
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22	30	36	—	—
5	—	—	—	—	.017	—	—	—	—	—	—	—	—	—	—	—	—	19	25	38	—
6	—	—	—	.011	.016	.025	.025	—	—	—	—	—	—	—	—	—	—	24	36	45	47
7	—	—	.008	.010	.014	.019	—	8	14	15	17	16	23	—	—	—	—	—	—	—	—
8	—	—	—	.011	.016	—	—	8	15	19	20	24	—	—	—	—	—	—	—	—	—

in N-567-54, and with *Fusulinella nevadensis* and *F. alta* in N-571-54 and in N-572-54.

FUSULINELLA ALTA V., T. & L., n. sp.
Pl. 134, fig. 1–12; Pl. 135, fig. 7–10

The shell of *Fusulinella alta*, n. sp., is moderately large for the genus; with almost straight to broadly arched or irregular axis of coiling, bluntly pointed polar ends, and an inflated central area, resulting in slightly concave lateral slopes. Larger shells of six and a half to eight volutions are 3.2 to 5.1 mm. long and 1.3 to 1.9 mm. wide, giving form ratios 2.3 to 2.9. The first volution is almost spherical with a form ratio of 1.0 to ellipsoidal with a ratio as great as 1.9. Beyond the first volution the axial ends become rapidly extended. Averages of the form ratios of the first to the eighth volution of six specimens are 1.4, 1.8, 2.1, 2.3, 2.4, 2.8, 2.8, and 2.7, respectively.

The proloculus is spherical in shape and measures 77 to 105 microns in outside diameter, averaging 90 microns for seven specimens. The chambers are lowest above the tunnel and they become higher gradually toward the polar ends where they attain their greatest height. Averages of the heights of the chambers above the tunnel in the first to the seventh volution of seven specimens are 38, 55, 76, 113, 147, 180, and 202 microns, respectively.

The spirotheca is typical of the genus and has a thin diaphanotheca with distinct upper and lower tectoria throughout the length of the shell. The diaphanotheca remains of about the same thickness to near the polar ends where it becomes indistinguishable. Averages of the thickness of the diaphanotheca plus the tectum above the tunnel in the second to the eighth volution of seven specimens are 9, 11, 13, 17, 20, 25, and 30 microns, respectively. The proloculus wall is too thin to measure accurately. Since this is evidently a late form of the genus, it would be expected that the wall would be considerably thicker than the above measurements indicate.

The septa are closely spaced in the inner three to four volutions, but they become more widely spaced in outer volutions. The septal counts for the first to seventh volution of one specimen are 7, 12, 16, 17, 15, 17, and 19, respectively. The general nature of the septa is closely similar to that of upper Derryan species, for they are almost plane throughout the central three-fourths of the shell and are not intensely fluted even in the extreme polar ends.

The tunnel is slightly less than half as high as the chamber, has an almost straight path, and becomes moderately broad in outer volutions of larger specimens. Averages of the tunnel angles in the third to the eighth volution of six specimens are 20, 20, 27, 31, 30, and 36 degrees, respectively. The chomata are almost half as high as the chambers in the center of the chambers, and they extend up both sides of the septa to the tops of the chambers. Their tunnel sides are steep to overhanging and their poleward slopes are very steep in the center of the chambers but are lower adjacent to the septa.

Remarks.—*Fusulinella alta* is stratigraphically one of the highest of the genus. It occurs with advanced *Fusulina*, *F. weintzi*, n. sp., which demonstrates that it is at least middle Desmoinesian in age. The evolutionary trends among forms of *Fusulinella* are not completely known. In many regions where *Fusulinella* is known from middle Derryan to within the lower Desmoinesian, its diaphanotheca gradually became thicker,

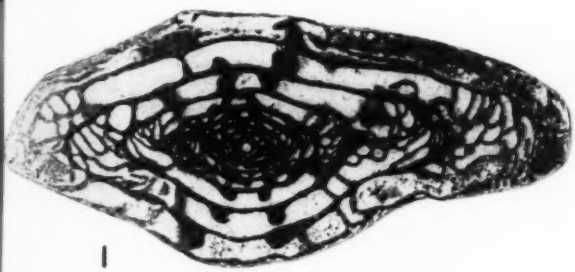
---

EXPLANATION OF PLATE 135

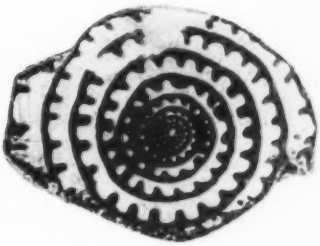
All illustrations on this plate are unretouched photographs, and all are magnified ×20.

FIG. *1–6.*—*Fusulinella nevadensis*, n. sp. *1,4,5*, Axial sections of paratypes; *2*, sagittal section of a paratype; *3*, axial section of the holotype; and *6*, tangential section of a paratype. Fig. *2* is of specimen 5 from N-572-54 and fig. *3* to *5* are of specimens 1,3, and 4 from N-571-54. Fig. *1* is from N-572-54, and *6* is from N-571-54.

7–10.—*Fusulinella alta*, n. sp. *7–9*, Axial sections; and *10* tangential section. Fig. *7* is from N-572-54, and *8* to *10* are from N-571-54.

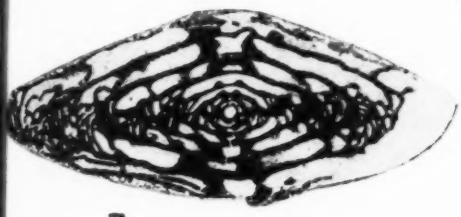


1

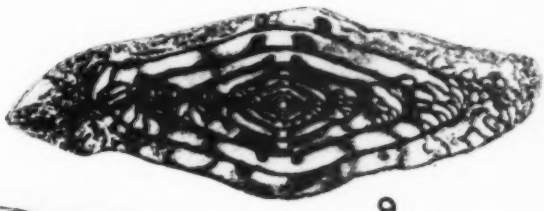


2

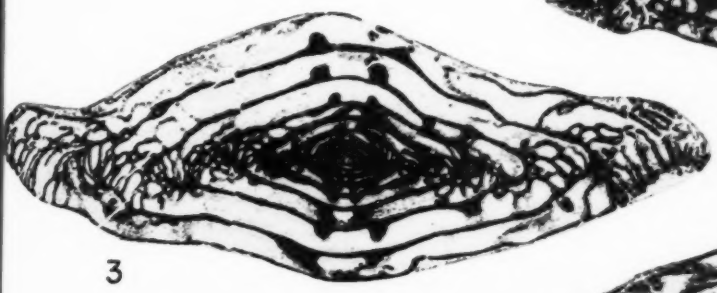
8



7

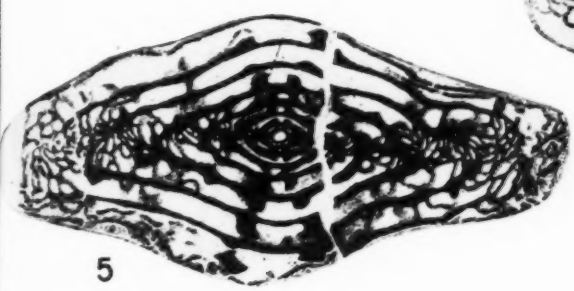


9

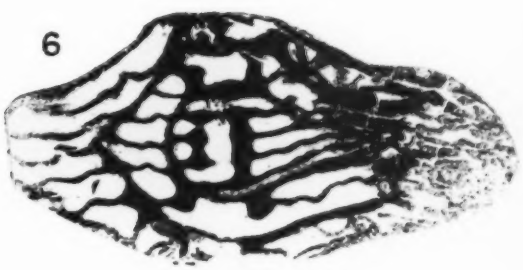


3

4

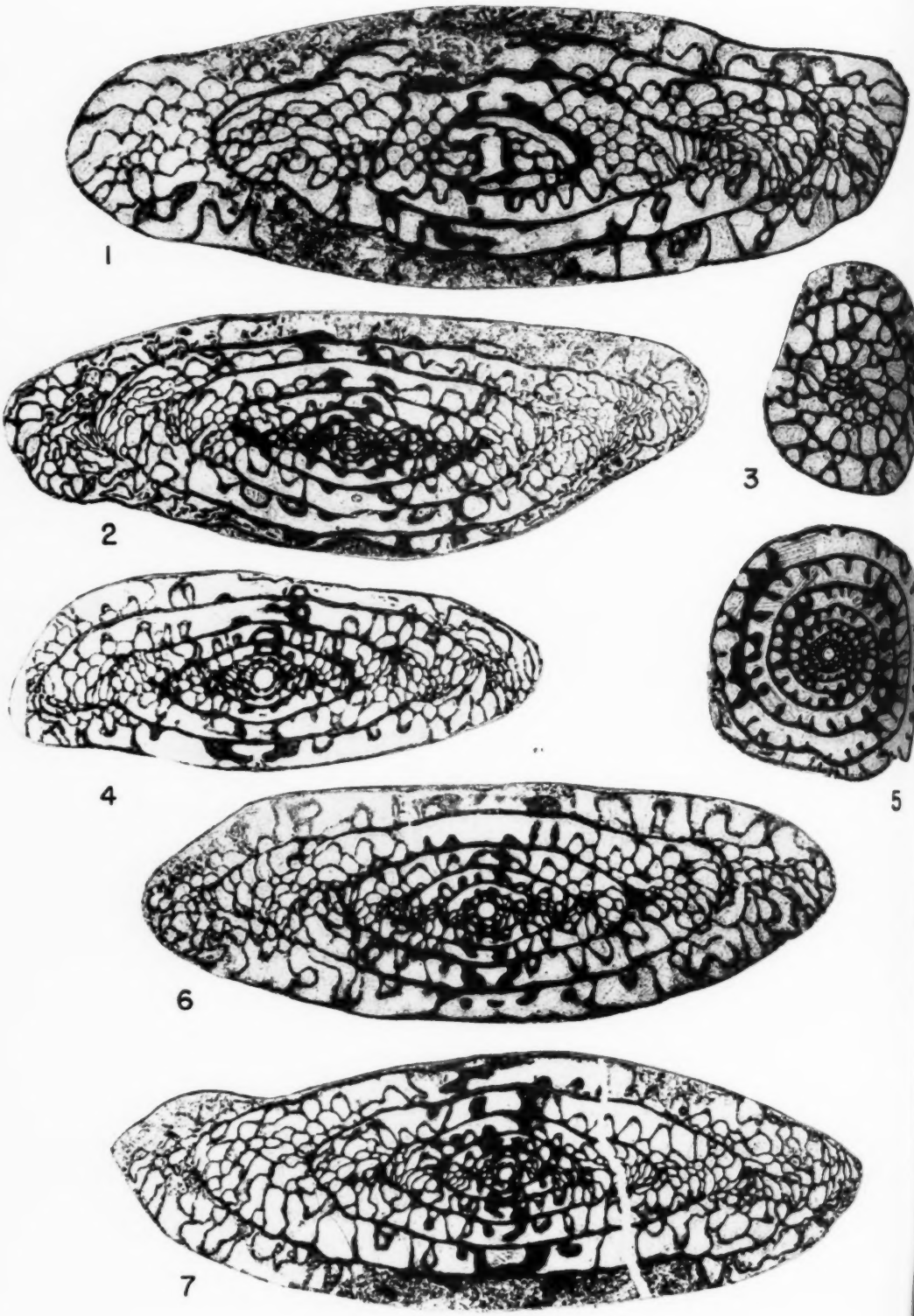


5



6

10


1
2
3
4
5
6
7

its septa became slightly but gradually more nearly completely fluted, and the shell became more elongate and larger. Although the shell of *F. alta* is larger than that of most other species of the genus and is more elongate than most, its diaphanotheca is thin and its septa are no more intensely fluted than most others. About the only indication of its late age is its large size.

Fusulinella alta resembles remarkably closely *F. devexa* Thompson from the Cuchillo Negro formation of New Mexico in general shell shape and growth but can be distinguished from the latter by its large shell, thicker diaphanotheca for corresponding volutions, and less massive and more narrow chomata.

The form described below as *Fusulinella nevadensis* can be distinguished from *F. alta* by the shorter shell, more inflated outer volutions, and the narrow but high chomata of the former.

Occurrence.—*Fusulinella alta* is abundant in collection N-567-54 where it is associated with abundant *Fusulina weintzi* and abundant *Bartramella bartrami?*. It is less common in collection N-572-54 and N-571-54 where it is associated with abundant *B. bartrami* and *Fusulinella nevadensis*. The above description is based entirely on the holotype and paratype specimens from collection N-567-54.

FUSULINELLA NEVADENSIS V., T. & L., n. sp.
Pl. 135, fig. 1–6

The shell of *Fusulinella nevadensis*, n. sp., is among the largest of the species of the genus, with larger specimens of seven and a half to eight volutions measuring 3.5 to 4.4 mm. long and 1.8 to 2.0 mm. wide and with form ratios of 1.8 to 2.4. The shell is elongate fusiform in shape and has a distinctly inflated central region, extended polar ends that are sharply pointed, deeply concave lateral slopes, and an irregular to almost straight axis of coiling. The first volution is ellipsoidal in shape with rounded ends, but beyond the first volution the ends become extended and pointed and become distinctly extended in about the fourth or fifth volution. Averages of the form ratios in the first to the eighth volution of three specimens are 1.1, 1.5, 1.7, 1.9, 2.1, 2.3, 2.3, and 2.4, respectively.

The proloculus is small and measures 65 to 95 microns in outside diameter, averaging 79 microns for three specimens. The chambers vary in height along their width. They are highest in the polar ends, decrease in height near the lateral concave areas, and are slightly higher above the tunnel of outer volutions where inflation is so distinct. Averages of the heights of the chambers above the tunnel of the first to the seventh volution of three specimens are 39, 62, 80, 93, 137, 174, and 213 microns, respectively.

The spirotheca is typical of the genus and is completely covered above and below with tectoria, except for the last volution. The diaphanotheca is thickest above the tunnel area and thins sharply in the polar regions. Averages of the thickness of the tectum and diaphanotheca of the third to the seventh volution of three specimens are 8, 10, 14, 16, and 33 microns, respectively. The proloculus wall and the spirotheca of the first two volutions are too thin for measurement.¶

The septa are distinctly fluted only in the extreme polar ends and are plane in their lower two-thirds across the central half of the shell. They are broadly fluted in their upper margins across the tunnel. The septal counts of the first to the eighth volution of one specimen are 9, 13, 16, 17, 16, 20, 24, and 29, respectively. The chomata are high and narrow, with steep to overhanging tunnel sides and steep poleward slopes in outer volutions. In the first three volutions they extend almost to the poles.

EXPLANATION OF PLATE 136

All illustrations on this plate are unretouched photographs, and all are magnified ×20.

FIG. *1–7*—*Fusulina weintzi*, n. sp. *1*, Tangential section of a paratype; *2*, axial section of the holotype; *3*, parallel section of a paratype; *4,6,7*, axial sections of paratypes; and *5*, sagittal section of a paratype. Fig. *2* and *4* to *7* are of specimens 1, 4, 5, 2, 3, respectively, from N-567-54.

Measurements of *Fusulinella alta*, n. sp. (N-567-54), in millimeters

Specimen	L.	W.	Ratio	No. vol.	Diam. of prol.	Height of volutions								Form ratio of volutions							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	4.6	1.6	2.8	7	.080	.055	.066	.096	.113	.161	.192	—	—	1.6	1.9	2.2	2.5	2.7	3.1	2.8	—
2	5.0	1.9	2.7	8	.077	.037	.048	.079	.093	.136	.185	.198	.234	1.9	1.9	2.1	2.4	2.4	2.8	2.7	2.7
3	—	1.7	—	7½	.099	.041	.056	.075	.104	.146	.176	.206	—	—	—	—	—	—	—	—	—
4	4.0	1.4	2.9	6½	.096	.036	.045	.068	.113	.154	.197	—	—	1.4	1.9	2.0	2.6	3.1	3.1	—	—
5	3.4	1.4	2.4	6½	.089	.029	.053	.061	.119	.144	.181	—	—	1.0	1.4	2.1	2.2	2.3	2.9	—	—
6	3.2	1.4	2.3	6½	.085	.034	.059	.091	.112	.134	.168	—	—	1.6	1.8	1.6	1.7	1.8	2.2	—	—
7	3.2	1.3	2.5	6½	.105	.032	.059	.083	.120	.155	.163	—	—	1.1	1.8	2.3	2.4	2.3	3.0	—	—

Specimen	Thickness of spirotheca								Septal count							Tunnel angle (degrees)							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
1	—	.013	.010	.014	.015	.021	.024	—	—	—	—	—	—	—	—	—	—	21	22	29	36	31	—
2	—	.009	.010	.012	.017	.024	.027	.030	—	—	—	—	—	—	—	—	—	—	21	25	33	28	36
3	—	.008	.013	.015	.017	.024	.025	—	7	12	16	17	15	17	19	—	—	—	—	—	—	—	—
4	—	.006	.008	.012	.015	.023	—	—	—	—	—	—	—	—	—	—	—	26	27	32	36	—	—
5	—	—	.010	.014	.017	.024	—	—	—	—	—	—	—	—	—	—	—	21	18	25	25	—	—
6	—	—	.012	.014	.018	.022	—	—	—	—	—	—	—	—	—	—	—	14	13	22	28	—	—
7	.006	.010	.012	.013	.019	.023	—	—	—	—	—	—	—	—	—	—	—	19	20	29	30	—	—

Measurements of *Fusulinella nevadensis*, n. sp. (N-571-54),* in millimeters

Specimen	L.	W.	Ratio	No. Vol.	Diam. of prol.	Height of volutions								Form ratio of volutions							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	4.4	1.8	2.4	8	.077	.041	.048	.080	.082	.102	.170	.207	—	1.0	1.3	1.7	2.0	2.1	2.3	2.2	2.4
3	3.5	1.9	1.8	8	.065	.040	.063	.077	.091	.147	.195	.245	—	1.1	1.3	1.6	1.7	1.8	2.3	2.1	—
4	4.0	1.8	2.2	7½	.095	.036	.075	.082	.106	.161	.156	.186	—	1.3	1.8	1.8	2.1	2.3	2.4	2.5	—
5	—	2.0	—	8	.073	.034	.043	.063	.089	.144	.179	.185	.208	—	—	—	—	—	—	—	—

* Specimen 5 is from Collection N-572-54.

Specimen	Thickness of spirotheca							Septal count								Tunnel angle (degrees)							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	—	—	.006	.007	.013	.017	.033	—	—	—	—	—	—	—	—	—	—	—	14	15	17	26	27	29
3	—	—	.007	.012	.014	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	20	23	24	—
4	—	—	.010	.011	.014	.023	.032	—	—	—	—	—	—	—	—	—	—	—	18	17	20	30	32	—
5	—	—	.011	.012	.017	.020	.030	9	13	16	17	16	20	24	29	—	—	—	—	—	—	—	—

Remarks.—*Fusulinella nevadensis* is one of the largest of the species of the genus and has a distinctly inflated central area. It can be distinguished from most species by its large shell, inflated outer volutions, and inflated central region. It is most closely similar to *F. alta* but differs from that species by its more symmetrical and narrow chomata, its inflated shape and smaller form ratios, and its resulting concave lateral slopes.

Occurrence.—*Fusulinella nevadensis* is rather common in collection N-571-54 and N-572-54 where it is associated with *Bartramella bartrami* and *F. alta*.

FUSULINA WEINTZI V., T. & L., n. sp.
Pl. 136, fig. 1–7

The shell of *Fusulina weintzi*, n. sp., is of moderate size for the genus and is elongate subcylindrical in shape; with bluntly pointed polar ends, very broadly curving lateral surfaces, and shifting axis of coiling. Larger shells of five and a half to seven and a half volutions are 4.2 to 5.6 mm. long and 1.5 to 1.9 mm. wide, giving form ratios of 2.7 to 3.3. The first volution is almost spherical and has a form ratio slightly greater than unit value, but the axial ends rapidly become extended from near the end of the first to the seventh volution. Averages of the form ratios of the first to the seventh volution of four specimens are 1.3, 1.7, 2.2, 2.3, 2.7, 2.9, and 2.8, respectively.

The proloculus is quite variable in size, varying from 89 to 185 microns in outside diameter and averaging 138 microns for five specimens. The shell expands rapidly for the first five volutions and only slowly from there to maturity. Averages of the heights of chambers above the tunnel in the first to the sixth volutions in five specimens are 48, 60, 96, 136, 190, and 213 microns, respectively. The chambers are lowest above the tunnel, become higher poleward, and are highest near the extreme polar ends. However, the lateral slopes are irregular and result in variable chamber heights, especially toward the polar ends.

The spirotheca is typical of the genus, with thin but irregular upper and lower tectoria. Averages of the thickness of the tectum plus the diaphanotheca in the second to the seventh volutions of five specimens

Measurements of *Fusulina weintzi*, n. sp. (N-567-54), in millimeters

Specimen	L.	Ratio	No. Vol.	Diam of prol.	Height of volutions							Form ratio of volutions						
					1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	5.3	1.8	2.8	7½	.089	.037	.050	.076	.130	.204	.192	—	1.4	1.7	2.2	2.2	2.5	2.6	2.8
2	5.2	1.8	2.9	6	.153	.055	.058	.096	.136	.210	.233	—	1.2	1.5	2.0	2.2	2.6	2.9	—
3	5.6	1.8	3.1	6	.140	.059	.073	.110	.167	.194	.250	—	1.4	2.2	2.6	2.6	3.2	3.1	—
4	4.2	1.5	2.8	5½	.185	.048	.075	.126	.157	.209	—	—	1.2	1.5	2.2	2.3	2.6	—	—
5	—	1.9	—	7½	.124	.041	.045	.072	.088	.135	.177	.180	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count							Tunnel angle (degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	.009	.010	.016	.018	.025	.042	—	—	—	—	—	—	—	—	—	26	32	36	31	45
2	—	.010	.012	.014	.024	—	—	—	—	—	—	—	—	—	—	—	21	25	31	43	—
3	—	—	.009	.012	.018	.028	—	—	—	—	—	—	—	—	—	—	23	25	29	40	—
4	.006	.011	.013	.017	.024	—	—	—	—	—	—	—	—	—	—	—	28	32	34	—	—
5	—	.005	.008	.012	.020	.022	.034	11	19	18	19	23	25	31	—	—	—	—	—	—	—

are 8, 10, 14, 21, 25, and 38 microns, respectively. The proloculus wall is too thin to measure accurately.

The septa are fluted throughout the length of the shell and closed chamberlets extend above the tunnel. However, the septa are broadly fluted at their upper margin above the tunnel. The septal fluting seems variable and irregular near the top of the chambers in the end quarters of the shell. The septal counts of the first to the seventh volution of a typical specimen are 11, 19, 18, 19, 23, 25, and 31, respectively.

The tunnel is almost straight and is about half as high as the chambers in outer volutions. Its angle averages 24, 28, 32, 38, and 45 degrees in the third to the seventh volutions, respectively, in four specimens. Chomata are narrow near the center of chambers but extend up the septa and along the septa for considerable distances with rapidly diminishing thickness. In fact, they cover the lower margins of the septa to give them pendant-shaped cross sections above the tunnel.

Remarks.—Although the overall size of *Fusulina weintzi* does not compare closely with the large sizes of many upper Desmoinesian species of the genus, such as *F. megista*, *F. mysticensis*, and *F. eximia* from the Marmaton group of Iowa, its loosely coiled shell, rather narrow chomata, and irregular septal fluting do suggest that it is an advanced form of the genus.

Fusulina weintzi resembles somewhat closely in general shell shape *F. leei* Skinner from the Cherokee of Oklahoma but can be distinguished from that form by its larger shell, more intensely fluted septa, more loosely coiled shell, and less massive chomata deposits in all volutions.

This species is named for Mr. C. A. Weintz.

Occurrence.—*Fusulina weintzi* is abundant in collection N-567-54, Cherry Creek Mountains, Nevada, where it is associated with abundant *Bartramella bartrami?*, and *Fusulinella alta*.

REFERENCES

DALMATSKAIA, I. I., 1951, New species of fusulinids from the lower part of the Middle Carboniferous deposits of the Russian Platform: Moskov. Obshch. Ispyt. Prirody, Trudy,

Otdel Geol., t. 1, p. 194–196, pl. 1. [In Russian]

KNIGHT, R. L., 1956, Permian fusulines from Nevada: Jour. Paleont., vol. 30, p. 773–792, pl. 83–88.

RAUSER-CERNOUSSOVA, D. M., BELJAEV, G. M., & REITLINGER, E., 1936, Die ober-paläozoischen Foraminiferen aus dem Petschoralande (Der Westabhang der Nord-Urals): Acad. Sci. U.S.S.R., Trans. Polar Comm., vol. 28, p. 159–232, pl. 1–6.

SKINNER, J. W., & WILDE, G. L., 1954, The fusulinid subfamily Boultoniinae: Jour. Paleont., vol. 28, p. 434–444, pl. 42–45.

TORIYAMA, RYUZO, 1953, New peculiar fusulinid genus from the Akiyoshi limestone of southwestern Japan: Jour. Paleont., vol. 27, p. 251–256, pl. 35, 36.

THOMPSON, M. L., 1948, Studies of American fusulinids: Univ. Kansas, Paleont. Contrib., Protozoa, Art. 1, p. 1–184, pl. 1–38.

——, VERVILLE, G. J., & LOKKE, D. H., 1956, Fusulinids of the Desmoinesian-Missourian contact: Jour. Paleont., vol. 30, p. 793–810, pl. 89–93.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1288–1314, PL. 137–144, 6 TEXT-FIG., NOVEMBER 1956

UPPER MIOCENE FORAMINIFERA AND FISH FROM THE LOS ANGELES AREA, CALIFORNIA

RICHARD L. PIERCE
Richfield Oil Corporation, Long Beach, California

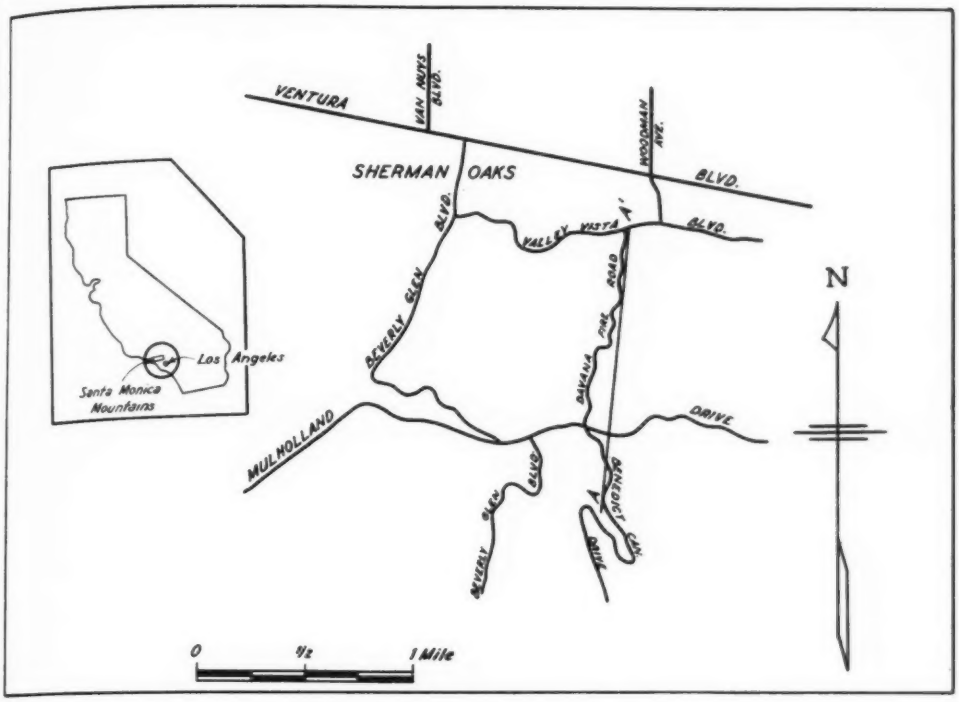
ABSTRACT—The frequency distribution of 88 species of Mohnian Foraminifera and 11 families of Mohnian fishes is covered in this study from Benedict Canyon, eastern Santa Monica Mountains (parts of sec. 27 and 34, T. 1 N., R. 15 W., Van Nuys quadrangle, Los Angeles County, Calif.). Of these Foraminifera, seven are new species and three are new varieties. A stratigraphic thickness of some 2,240 feet, consisting of northward-dipping siliceous shales, massive sandstones, cherty shale and punky diatomaceous shale (older to younger rocks, respectively), is exposed at this locality. The bedding planes of 140 samples were examined for fish scales, fish skeletons and Foraminifera, and later were washed to obtain material for the frequency study of Mohnian Foraminifera. It is demonstrated that these Mohnian sediments subdivided, locally, by the use of either Foraminifera or fish scales, into three easily recognized zones: the lower zone, *Bulimina uvigerinaformis-Etringus scintillans* zone; the middle zone, *Bolivina benedictensis-Xyne grex* zone; the upper zone, *Bolivina granti-Lampanyctus bolini* zone. Some of the other striking results are: the Modelo formation at this locality was probably deposited within the bathyal zone; the fish remains aid in a better evaluation of the ecology of the Mohnian Foraminifera in the Benedict Canyon section; and a new systematics for the description of fossil fish scales is proposed.

INTRODUCTION

THE purpose of this study was to try and zone the Modelo formation in the eastern Santa Monica Mountains, by using both Foraminifera and fish scales. The upper Miocene foraminiferal assemblages of the Modelo formation in the eastern Santa Monica Mountains have been studied rather extensively because of their stratigraphic value in the petroleum industry, however, very little stratigraphic work has been done with the floods of fish scales that are found in this formation, with the exception of the work of Lore Rose David (1944, p. 34–41). One of the important objectives of this investigation was to develop criteria for correlating Modelo sediments by fish scales where Foraminifera are unrecognizable or missing. The area under discussion is located in Benedict Canyon, eastern Santa Monica Mountains, in parts of sec. 27 and 34, T. 1 N., R. 15 W., Van Nuys quadrangle, Los Angeles County, Calif. (Text-fig. 1).

All original samples were collected in 1943 by Tom Baldwin, senior geologist with Monterey Oil Company. Baldwin's localities were resampled for fish scales and these together with the original samples provide the basis for this paper. The field and laboratory work was started in the fall of 1952. One hundred and forty samples were collected at approximately 15-foot stratigraphic intervals. The bedding planes of these samples were first examined for fish scales and Foraminifera, then washed for foraminiferal study. All foraminiferal figures were drawn by the author, using a camera lucida for outlining the structures. Fish scales were photographed and retouched.

The writer is indebted to the following people and agencies for their assistance and cooperation in aiding in this study: Dr. O. L. Bandy, University of Southern California, for first calling the writer's attention to the problem, for many suggestions, and for encouragement extended by him; Dr. W. H. Easton and Dr. R. H. Merriam of the University of Southern California have also added to this work with their suggestions; Miss Janet Haig, of Hancock Foundation, University of Southern California, for her assistance in the fish study; Mr. T. Baldwin senior geologist with Monterey Oil Company, for allowing the writer to use his foraminiferal samples of Benedict Canyon; Richfield Oil Corporation, for allowing the writer to collect samples for the fish study as a part of his training program; Dr. M. L. Hill, chief geologist of Richfield Oil Corporation, for allowing the writer to include



TEXT-FIG. 1—Location of sampled area.

the fish study with his thesis; Dr. M. L. Natland, of Richfield Oil Corporation, for the use of his microphotographic equipment and his helpful suggestions in the field work; Mr. W. T. Rothwell, Jr., also of the Richfield Oil Corporation, for his valuable assistance and criticism of this study; Mr. D. W. Duncan, Mr. L. C. Larson, and Mr. R. E. Staton, for their assistance in photographing the fish scales; Mr. C. M. McRaven, for his work in drafting the charts; and Mr. H. C. Paris, for his technical assistance in preparing the typescript. The study represents part of a thesis submitted for the degree of Master of Arts at the University of Southern California.

STRATIGRAPHY

The type section of the Modelo formation is located in Modelo Canyon, a branch of Piru Creek, which is in the northeast part of the Piru quadrangle, in Ventura County, or about 20 miles northwest of the area covered by this paper. The Modelo formation, as mapped by Kew, included all the Miocene section above the Vaqueros sandstone in Modelo Canyon (Bramlette, 1946, p. 8); it contains rocks older than those which comprise the Modelo in the eastern part of the Santa Monica Mountains. M. N. Bramlette (1946, p. 8) states "the thick mudstone forming the lower part of Kew's Modelo formation is not exposed in Modelo Canyon but is exposed in nearby areas. It is correlated with the Rincon mudstones." The lithologic members above the mudstone of Kew's Modelo formation are of middle and upper Miocene age according to Bramlette (1946, pl. 2). H. W. Hoots (1931, p. 102) states that "because of the striking unconformity in the Santa Monica Mountains between the Topanga and the Modelo, it is a simple task to separate the two formations, and this necessary separation has resulted in a restricted use of the name Modelo."

The Modelo of this paper includes only Kleinpell's Mohnian stage. A stratigraphic thickness of approximately 2,240 feet was sampled (Text-fig. 3). These beds are characterized by siliceous and cherty shales,

massive sandstones, cherty shales, and laminated diatomaceous shales and siliceous mudstones (oldest to youngest, respectively).

LITHOLOGY

The Modelo is predominantly a shaly formation, and for this reason most of it presents a strong contrast to other formations in the eastern part of the Santa Monica Mountains (Text-fig. 2). In Benedict Canyon the Mohnian part of the Modelo may be subdivided generally into 3 lithologic units which are in ascending order:

(1) lower unit consisting of light-gray to chocolate-brown, thin-bedded, hard, platy, siliceous shale, alternating with yellowish-brown, hard, platy, cherty shale and massive units of coarse gray and brown sandstones;

(2) middle unit much like that of the above, except for a greater portion of gray-to-brown massive sandstone; and

(3) the upper unit consisting of white, punky, laminated, diatomaceous shale, alternating with light-gray, siliceous mudstone, and with thin streaks of silts and sands. Generally, floods of fish scales are found in "punky" diatomaceous shale, siliceous mudstone, and cherty shale.

FAUNAL CHARACTERISTICS

Foraminifera

The Modelo microfauna of Benedict Canyon, described in this study, consists predominantly of smaller benthonic forms and a very small number of pelagic species. Following Galloway's classification, there are 10 families, 38 genera, and 88 species and varieties. The more abundant and characteristic genera, in decreasing order of abundance, are: *Bolivina, Uvigerina, Globigerina, Cassidulinella, Buliminella, Gyroidina, Discorbinella, Epistominella, Cassidulina* and *Bulimina.*

Where possible, each washed sample was split until approximately 300 specimens remained, then frequency counts were made. A total of about 20,000 specimens were counted. Table 1 shows the percentage-abundance count and the stratigraphic ranges of 88 species and varieties of the Modelo formation in the Benedict Canyon section. As indicated by the stratigraphic ranges of the Foraminifera in Table 1, the Modelo formation at this locality may be divided into three foraminiferal zones: lower

---

EXPLANATION OF PLATE 137

FIG. *1*—*Nodosaria tympaniplectiformis* Schwager, ×34; a, side view; b, apertural view; hypotype, USC No. 3545.

2—*Dentalina* cf. *D. barnesi* Rankin, ×46; a, side view; b, apertural view; hypotype, USC No. 3546.

3—*Dentalina monicana* Pierce, n. sp., ×35; a, side view; b, apertural view; holotype, USC No. 3547.

4—*Frondicularia* sp., ×42; a, side view; b, apertural view; hypotype, USC No. 3548.

5—*Lagena scalariformis* (Williamson), ×72, a, side view; b, apertural view; hypotype, USC No. 3549.

6—*Lagena striato-punctata* Parker & Jones var. *pentacosta* Pierce, n. var., ×72; a, side view; b, apertural view; holotype, USC No. 3550.

7—*Fissurina tricostulata* Pierce, n. sp., ×64; a, side view; b, apertural view; holotype, USC No. 3551.

8—*Nonion goudkoffi* Kleinpell, ×63; a, side view; b, apertural view; hypotype, USC No. 3552.

9—*Nonionella belridgensis* (Barbat & Johnson), ×42; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3553.

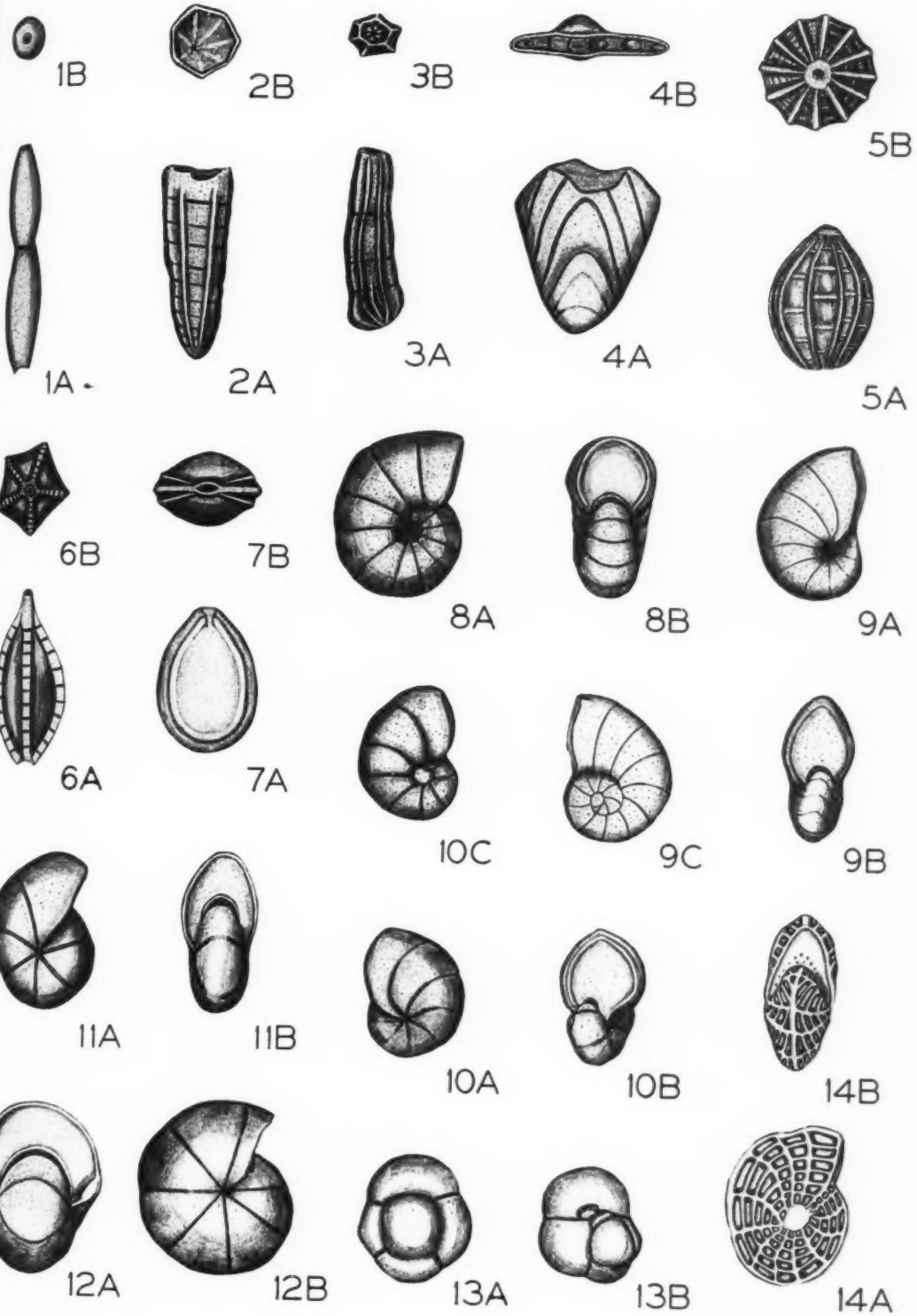
10—*Nonionella davanaensis* Pierce, n. sp., ×40; a, ventral view; b, apertural view; c, dorsal view; holotype, USC No. 3554.

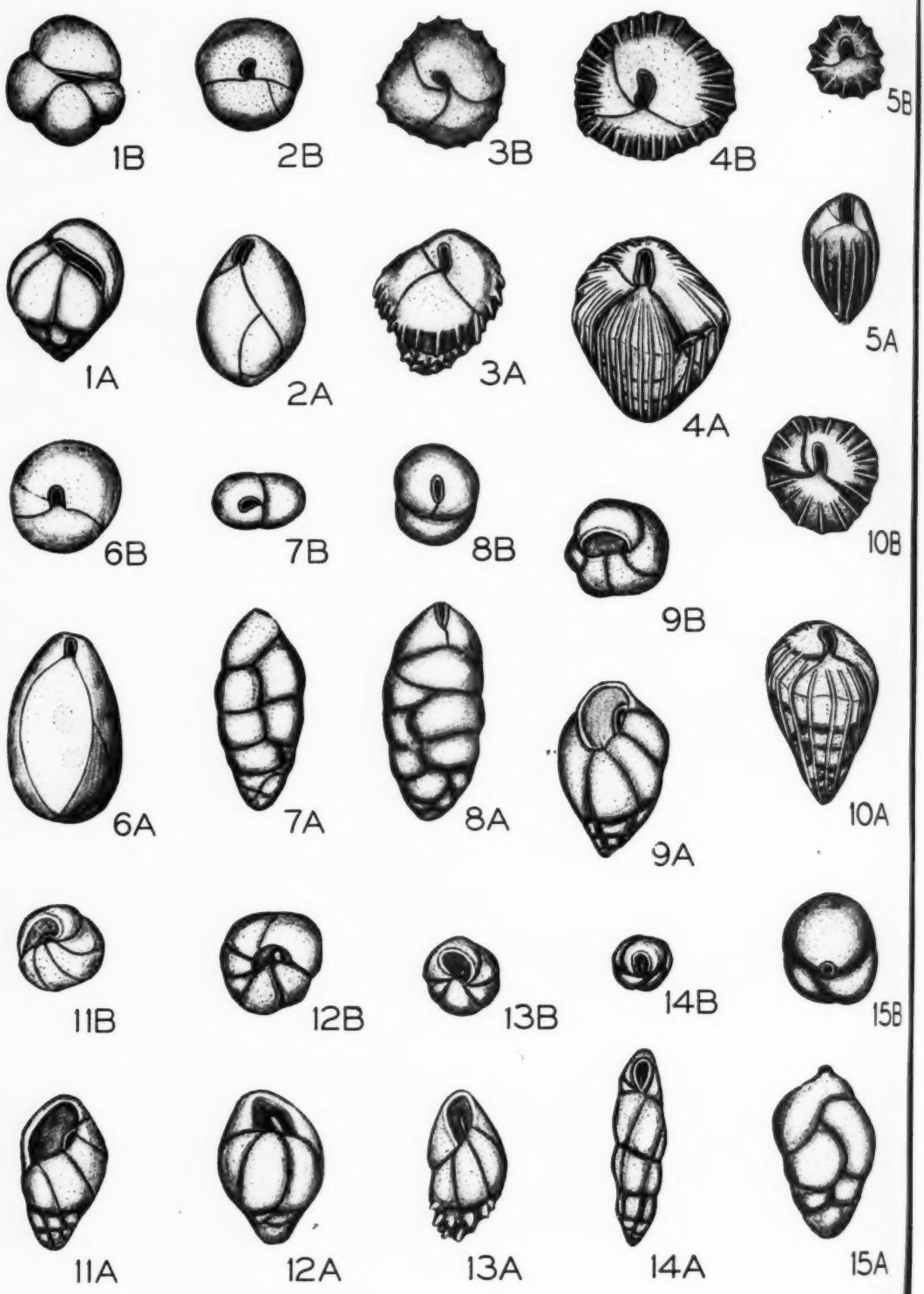
11—*Pullenia salisburyi* R. E. & K. C. Stewart, ×76; a, side view; b, apertural view; hypotype, USC No. 3556.

12—*Pullenia* cf. *P. miocenica* Kleinpell, ×56; a, side view; b, apertural view; hypotype, USC No. 3555.

13—*Sphaeroidina bulloides* d'Orbigny, ×38; a, dorsal view; b, ventral view; hypotype, USC No. 3558.

14—*Elphidium granti* Kleinpell, ×44; a, side view; b, apertural view; hypotype, USC No. 3557.


1B
2B
3B
4B
5B
1A
2A
3A
4A
5A
6B
7B
8A
8B
9A
6A
7A
10C
9C
9B
11A
11B
10A
10B
14B
12A
12B
13A
13B
14A


1B
2B
3B
4B
5B
1A
2A
3A
4A
5A
6B
7B
8B
9B
10B
6A
7A
8A
9A
10A
11B
12B
13B
14B
15B
11A
12A
13A
14A
15A

zone, *Bulimina uvigerinaformis;* middle zone, *Bolivina benedictensis* and *Cassidulinella renulinaformis;* and upper zone, *Bolivina granti.*

Bulimina uvigerinaformis zone.—This species appears between sample 116 and sample 136 (Table 1). The interval from sample 137 to 145 may be, in part, equivalent to Kleinpell's *Bolivina modeloensis* zone. However, foraminiferal control is lacking in this part of the section and also just below the angular unconformity between the Modelo formation and the underlying Topanga formation (Table 1 and Text-fig. 2b). Conformably overlying the above zone, is a biozone which has been called the *Bolivina hughesi* zone, but in this study it will be referred to as the *Bolivina benedictensis* and *Cassidulinella renulinaformis* zone. The holotype specimen of *Bolivina hughesi* Cushman, 1926, does not agree with the original figure by Cushman. The writer has chosen the name, *Bolivina benedictensis,* for this new species because it was first correctly figured and described from the Benedict Canyon study.

Bolivina benedictensis and *Cassidulinella renulinaformis* zone.—This faunal zone is characterized by the restricted occurrence of *Bolivina benedictensis* and *Cassidulinella renulinaformis.* These two species were found to occur no higher than sample 37. *Bolivina benedictensis* was found to occur no lower than sample 108, and *Cassidulinella renulinaformis* was found to occur no lower than sample 115 (Table 1 and Text-fig. 3). *Cassidulinella renulinaformis* was not found in many of the washed samples probably because it is a very fragile form and is usually broken during the washing process. Its stratigraphic range and abundance were determined by examining the bedding planes of each sample (see legend of Table 1). Conformably overlying this zone is the *Bolivina granti* zone.

Bolivina granti zone.—This faunal zone is characterized by the restricted occurrence of *Bolivina granti,* which occurs between sample 16 and sample 33 (Table 1). Upon examining the holotypes and the paratypes of both *Bolivina granti* Rankin and *Bolivina goudkoffi* Rankin the writer found these two species to be conspecific. Inasmuch as the former has page priority these two species have been lumped into one species, *Bolivina granti* Rankin, in this study.

Fish

The Modelo fish-fauna at this locality consists almost entirely of pelagic free

---

EXPLANATION OF PLATE 138

FIG. *1*—*Allomorphina trochoides* (Reuss), ×53; a, side view; b, apertural view; hypotype, USC No. 3559.

2—*Bulimina ovula* d'Orbigny, ×50; a, side view; b, apertural view; hypotype, USC No. 3560.

3—*Bulimina pagoda* Cushman var. *hebespinata* R. E. & K. C. Stewart, ×48; a, oblique to the axis to show aperture better; b, apertural view; hypotype, USC No. 3561.

4,10—*Bulimina uvigerinaformis* Cushman & Kleinpell, ×31; a, oblique to the axis to show aperture better; b, apertural view; hypotype, USC No. 3563. 4, Megalospheric. 10, Microspheric.

5—*Bulimina rostrata* Brady, ×55; a, side view; b, apertural view; hypotype, USC No. 3562.

6—*Globobulimina pacifica* Cushman, ×31; a, side view; b, apertural view; hypotype, USC No. 3564.

7—*Virgulina californiensis* Cushman, ×30; a, side view; b, apertural view; hypotype, USC No. 3565.

8—*Virgulina californiensis* Cushman var. *grandis* Cushman & Kleinpell, ×32; a, side view; b, apertural view; hypotype, USC No. 3566.

9—*Buliminella brevior* Cushman, ×66; a, side view; b, apertural view; hypotype, USC No. 3567.

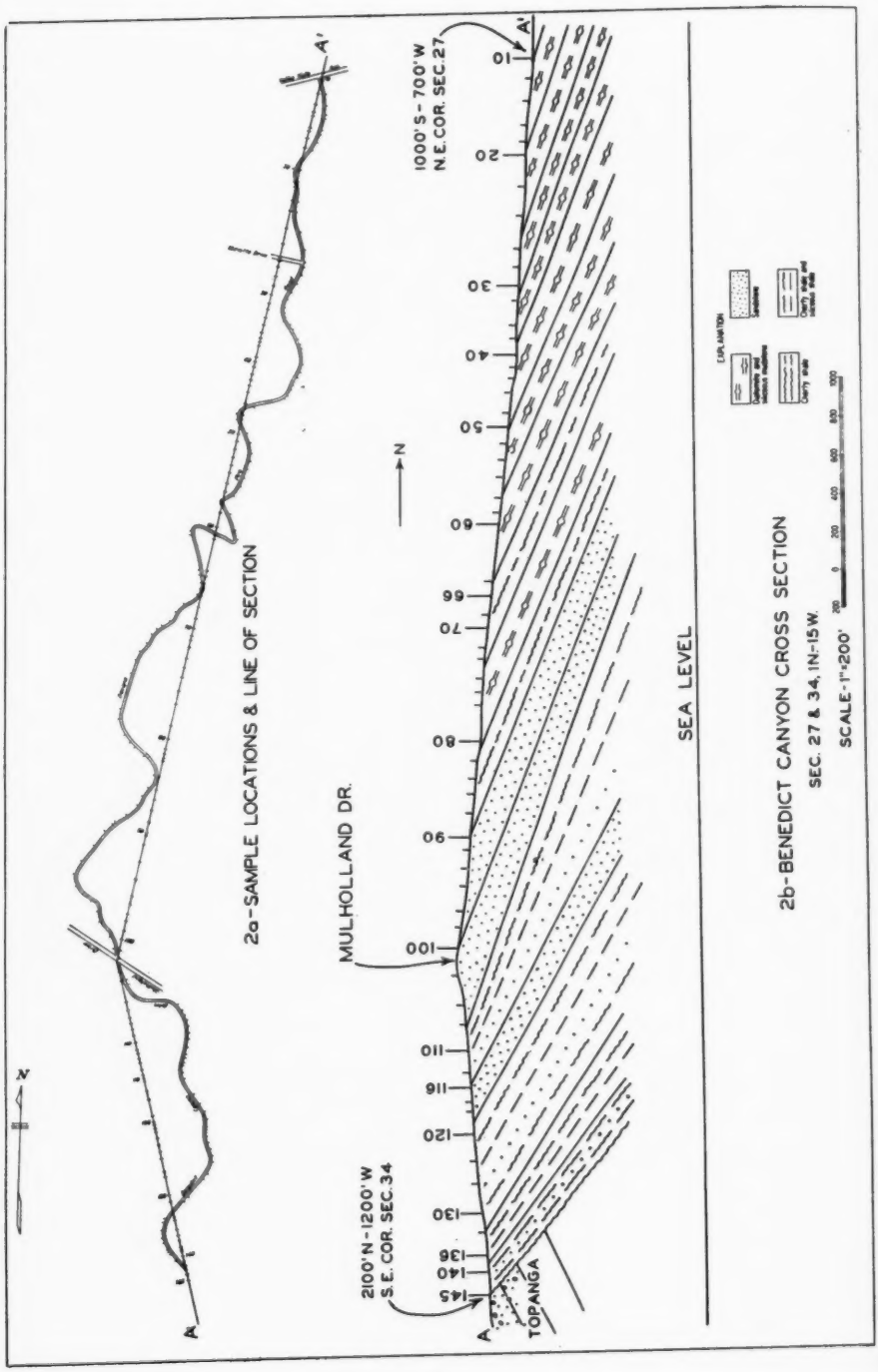
11—*Buliminella curta* Cushman, ×50; a, side view; b, apertural view; hypotype, USC No. 3568.

12—*Buliminella madagascarensis* (d'Orbigny), ×40; a, side view; b, apertural view; hypotype, USC No. 3569.

13—*Buliminella semihispida* Kleinpell, ×42; a, side view; b, apertural view; hypotype, USC No. 3570.

14—*Buliminella subfusiformis* Cushman, ×34; a, side view; b, apertural view; hypotype, USC No. 3571.

15—*Uvigerina hootsi* Rankin, ×40; a, side view; b, apertural view; hypotype, USC No. 3572.


2a-SAMPLE LOCATIONS & LINE OF SECTION
A
A'
N
MULHOLLAND DR.
2100'N-1200'W
S.E. COR. SEC.34
1000'S-700'W
N.E.COR. SEC.27
SEA LEVEL
TOPANGA
2b-BENEDICT CANYON CROSS SECTION
SEC. 27 & 34, 1N-15W.
SCALE-1"=200'
EXPLANATION

TEXT-FIG. 2

TABLE Nº 1

FIGURES IN %

✓ LESS THAN 1.50%

FORAMINIFERA	10A	10B	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	27A	27B	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Uvigerina hootsi	29	13						8		26						20	8		50												✓					
Uvigerina hispidocostata	5	3						✓		✓						✓	2	100								21	16				3			13		
Gyroidina multicamerata	4	2								14						3															✓			✓		
Globigerina bulloides	4	2								14							2									13	46		99	5	98					
Bolivina woodringi	5	4						6		6						11	16									53	17			11			✓		
Bolivina pseudospissa	12	18						2		3						19	8									4						✓		9		100
Bolivina decurtata	3	9						2		12						12	19		30																	
Bolivina tongi	6	✓						3		✓																										
Buimina pagoda var hollispinata	1	✓						✓		✓																					✓					
Gyroidina keenani	3	28								4						✓	2																			
Planulina ornata	9	2						2																		✓				20			6		
Orbulina universa	✓	✓																																		
Buimmella subfusiformis	9	2						35								3										3	✓								
Globorotalia canariensis	✓	✓																																		
Globorotalia scitula	✓	✓																														✓				
Siphonodosaria advena	✓	✓								✓																										
Gyroidina soldanii var rotundimargo	3							✓									4									2					✓	✓				
Angulogerina occidentalis	3															3	6																			
Bolivina fumida var cuneata	✓									7						✓	4									✓			✓							
Bolivina sinuata	✓	✓															3																			
Epistomineila subperuviana		7															4									2				✓		100	✓			
Valvulineria alicia microspheric		✓																																		
Cassidulina delicata		3						2																												
Epistomineila dascorbaoides		✓																																		
△ Bolivina granti								35		3																✓										
Nonion gaudefffi								6																												
Nodosaria tympaniplectriformis										3																										
Bolivina dawsi										3																										
Nonionella bertodgensis										✓																										
Discorbinella yamorteensis										✓						✓																				
Gyroidina keenani var. murietta										✓						7																				
Valvulineria araucana var malagaensis																✓																				
Anomalina schmitti																✓												✓								
Buimmella brevior																3										✓										
Valvulineria californica var obesa																✓																				
Pullenia salisburyi																✓										✓										
Hanzawaia illingi																✓																				
Cibicides fletcheri																	2																			
Buccella mansfieldi																	2																			
Buimmella curta																	2																			
Frandicularia sp.																											✓									
Bolivina fumida																													✓	✓						
Dentalina moncana																														9						
Rotalia garveyensis																														11			11	100		
Nononella davanensis																														6						
◻ ✕ Cassidulinella renulinaformis																																				
Bolivina girardensis																														✓	✓					
Epistomineila smithi																														3			9			
◻ Bolivina benedictensis																														✓						
Valvulineria alicia megalaugheric																																				
Bolivina vaughani																																				
Cassidulina panzana																																				
Bolivina marginata var mancana																																				
Suggrunda californica																																				
Spheroidina bulloides																																				
Buimmella semihispida																																				
Bolivina bramlettei																																				
Buimina ovula																																				
Cassidulina modelbensis																																				
Siphonodosaria irregularis																																				
Eponides heaidi																																				
Bolivina barbarana																																				
Cassidulina barbarana																																				
Bolivina salinasensis																																				
Virgulina californensis var grandis																																				
Virgulina californensis																																				
Bolivina hughesi																																				
Bolivina semiruda var hollisi																																				
Dentalina cf barnesi								8 +																												
Suggrunda kierspelli																																				
Bolivina perrini																																				
Buccella frigida																																				
Pullenia cf miocenica																																				
Buimmella madagascariensis																																				
Bolivina pacificana																																				
Lagena striato-punctata var pentacosta																																				
Elphidium grantii																																				
Lagena scalariformis																																				
Bathysiphon arenaceous																																				
Fissurina tricostulata																																				
Bolivina californica																																				
Globobulimina pacifica																																				
Bolivina brevior																																				
Allomorphina trochoides																																				
Uvigerina modeloensis																																				
+ Buimmina uvigeriniformis																																				
Uvigerina semicosta																																				
Buimmina rostrata																																				
Uvigerina rothwelli																																				
NUMBER OF SPECIMENS COUNTED	76	165						84		74						214	53	1	2							362	288		305	294	312	2	211	1	1		
FISH SCALES																																				
Pseudoseriola sp.		100											13									80	15			10					9					
◻ △ Pyne gres			27	33			36		9				33			11	64					20	2		8			100			100	27	67	40		67
△ Lampanctus bolini			18	33		10		50									9						6	26	46											
Atherinidae — N91			27	33			18	50															2	9												
Lampogaua retropes			9						27	16			13	66	43	29	9									100					33		10	17		
Sarda cf. sloani			9			13			18	11	11		15										57													
Sebastodes aff elongatus			9						9	11	22						9									50					9					
Decapterus (Lampochites) cf hopkinsi						17																	19	35							65		60		17	100
Ganolytes aratus							36		36		22	100	66	40	33	57								9												
Atherinidae — N94							13			22																										
Atherinidae — N92											33						9														9		20	10		
Pneumatophorus cf. grex											11												22	46												
Lampogaua culveri																																				
◻ + Etrumeus sconthians																																				
Ganolytes sp. cf. G. ramesi																																				
NUMBER OF SPECIMENS COUNTED		1	11	3		6	8	2	11	9	9	5	3	8	3	7	7	11				5	53	23	13	2	1	1		7	11	6	3	2	6	3
FISH SKELETONS																																				
△ Bathylagus (Quesita) argalensis																						100	78													
△ Lampanctus bolini																							22													
NUMBER OF SPECIMENS COUNTED																						11	9													

LEGEND – ✕ Cassidulinella renulinaformis (bedding plane count) ■ Flood 50+ ● Very abundant 20 to 50 ⊗ Abundant 8 to 19 X Common 3 to 7 / Rare 1 to 2
△ Late Upper Mohnian markers ◻ Early Upper Mohnian markers ◻ Very early Upper Mohnian markers + Lower Mohnian markers

STRATIGRAPHIC DISTRIBUTION OF MOHNIAN FORAMINIFERA AND FISH FROM
BENEDICT CANYON, SANTA MONICA MOUNTAINS, SHERMAN OAKS, CALIFORN

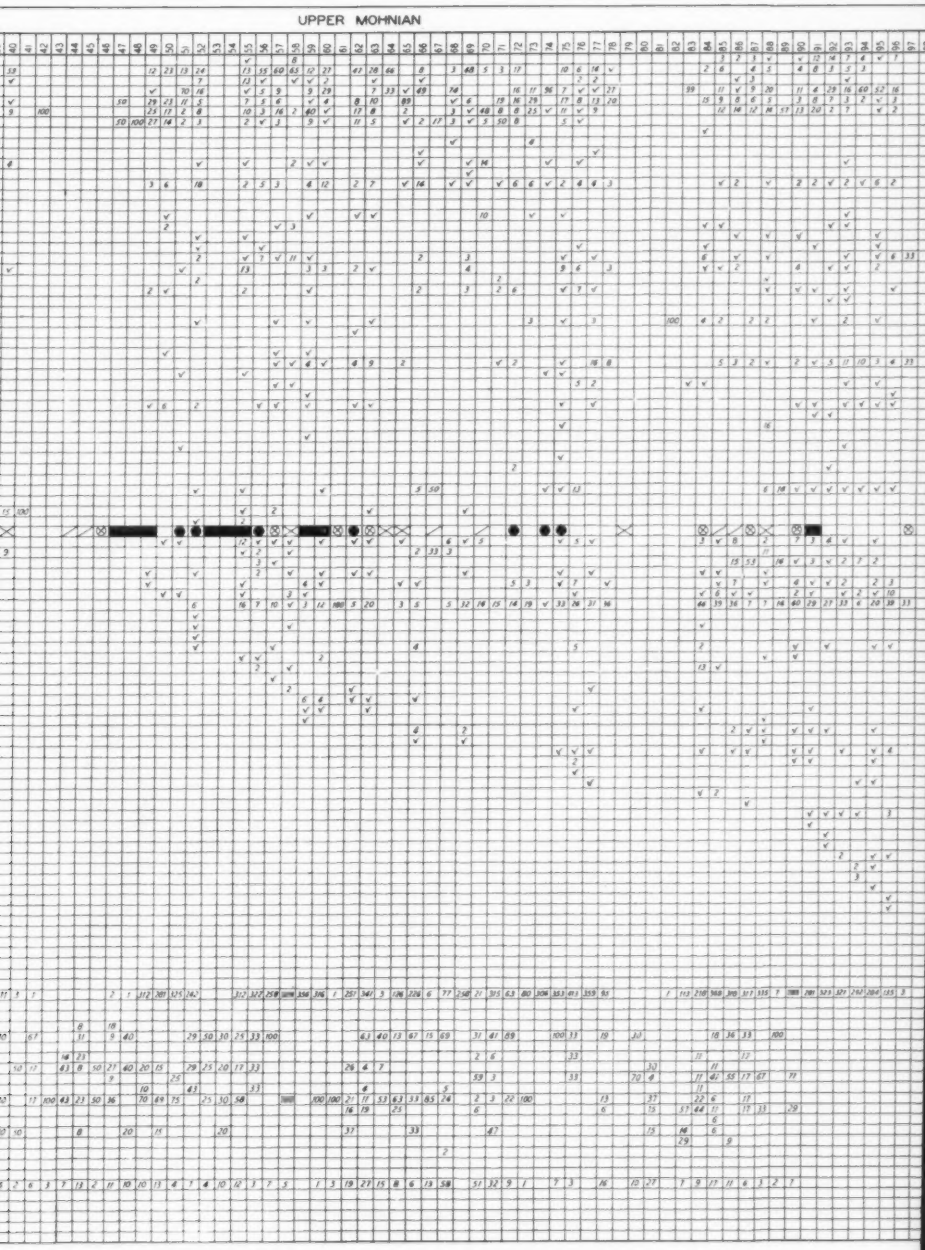
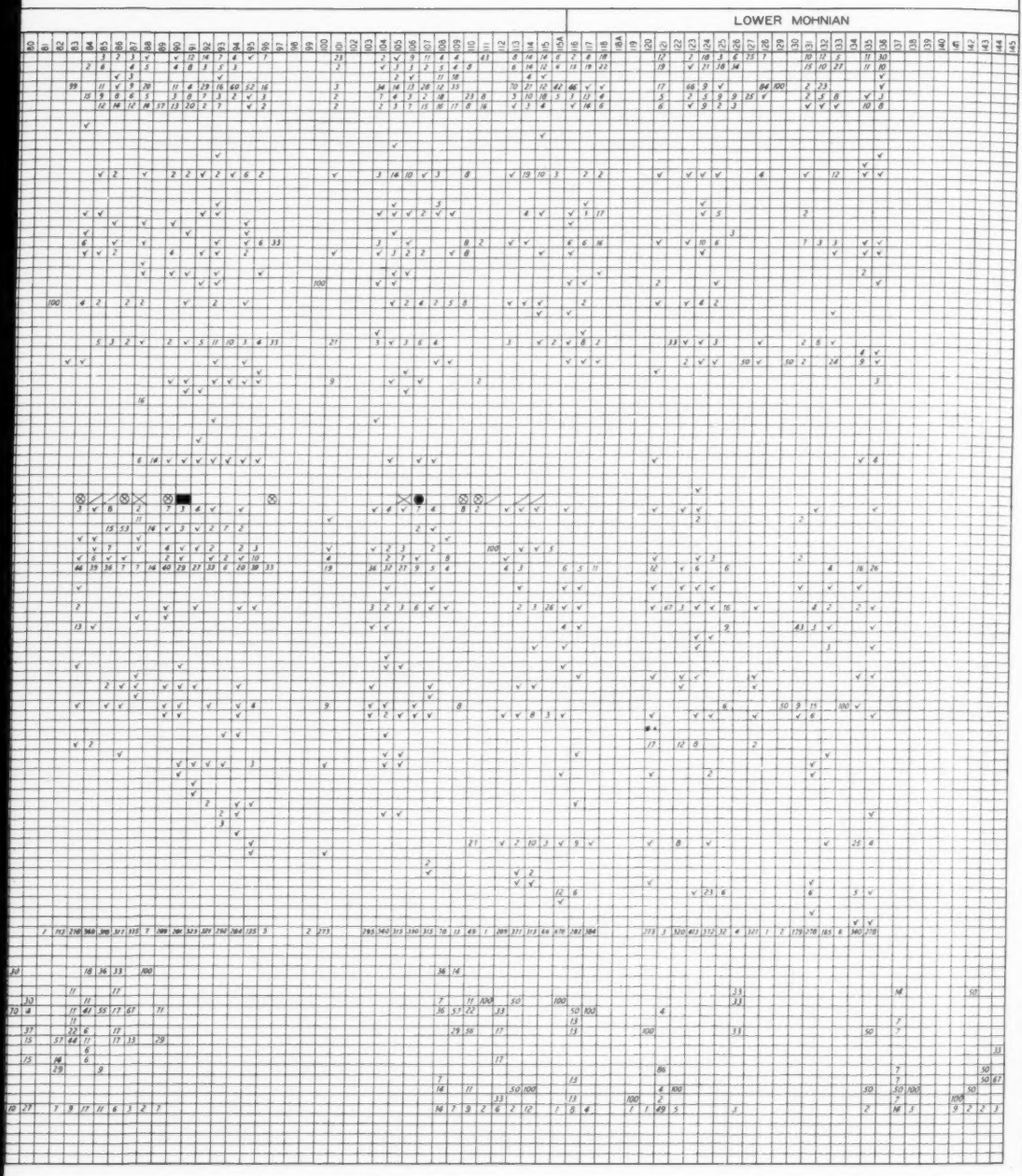
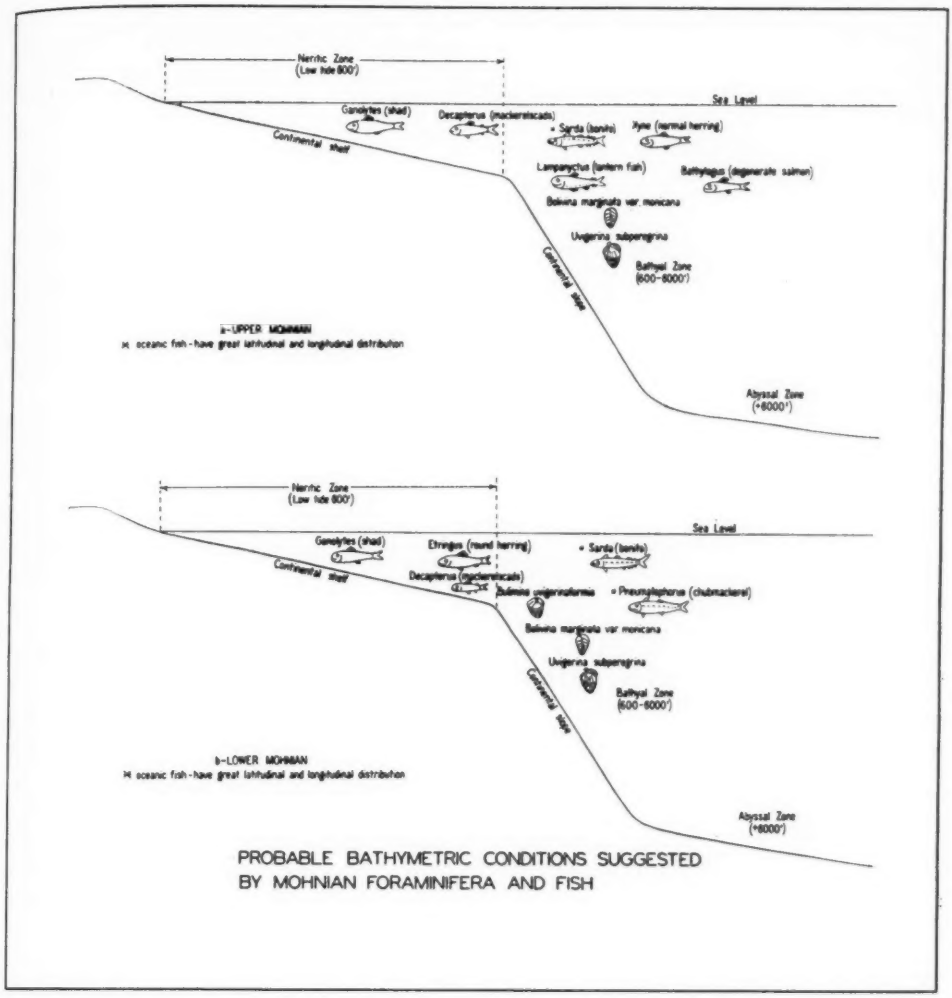


TABLE 1

FORAMINIFERA AND FISH FROM
AINS, SHERMAN OAKS, CALIFORNIA





TEXT-FIG. 3

swimmers, with only two genera, *Lompoquia* and *Sebastodes*, being bottom swimmers. Following Lore Rose David's classification (1943, p. 1–193), there are 11 families, 12 genera, and 13 species (possibly 16 species, because three of the fish scales described herein are from an undescribed genus and species). The more common and characteristic forms are: *Xyne*, *Decapterus*, *Sarda*, *Lompoquia*, *Atherinidae* (undescribed genus and species), *Pneumatophorus*, *Etringus*, and *Lampanyctus*.

An abundance count of 889 fish scales and 20 fish skeletons was made. The stratigraphic ranges of at least 14 species of fish within the Modelo formation at this locality were determined by examining the bedding planes of each sample (Table 1). The stratigraphic distribution chart and the stratigraphic column show that the Mohnian stage of the Modelo formation can be locally divided into three zones: lower zone, *Etringus scintillans;* middle zone, *Xyne grex;* and the upper zone, *Lampanyctus bolini* and *Bathylagus* (*Quaesita*) *angelensis.*

Etringus scintillans zone.—This zone is generally equivalent to the *Bulimina uvigerinaformis* zone. Locally, this round herring

scale was found to occur as high in the section as sample 109, or approximately 100 feet stratigraphically above the top of the *Bulimina uvigerinaformis* zone, and it occurs as low as sample 143. The presence of *Etringus scintillans* indicates lower Mohnian or earliest upper Mohnian in this locality.

Xyne grex zone.—This zone is in part equivalent to the *Bolivina benedictensis* and *Cassidulinella renulinaformis* zone. Although *Xyne grex*, normal herring scale, occurs from sample 110 to sample 10B (Table 1), it was chosen to represent the middle fish zone because, first, its lowest stratigraphic occurrence provides a rather good division from the *Etringus scintillans* zone, even though these two, *Xyne grex* and *Etringus scintillans*, overlap about 30 feet stratigraphically; and, second, *Xyne grex* occurs more abundantly in the *Bolivina benedictensis* and *Cassidulinella renulinaformis* zone than elsewhere. Lore Rose David (1943, p. v, 117) has reported the occurrence of this scale in early Delmontian sediments at Lompoc, California.

Lampanyctus bolini and *Bathylagus* (*Quaesita*) *angelensis* zone.—These two species, *Lampanyctus bolini*, lantern fish, and *Bathylagus* (*Quaesita*) *angelensis*, referred to as a degenerate salmon by some ichthyologists, were found not to occur below sample 32, thus representing a fish faunal zone equivalent to the *Bolivina granti* zone at this locality (Text-fig. 3).

Locally, these Mohnian fish scale markers may be very useful in helping to solve stratigraphic problems under the following conditions:

(1) where Foraminifera are too weathered or are crushed beyond identification, or the sediments are barren of Foraminifera;

(2) where Foraminifera are present but Mohnian foraminiferal markers are absent;

(3) where correlation by electric logs is impossible, due to the lenticular nature of some sands and shales.

Inasmuch as the parts of a typical teleostean fish scale have been illustrated by Lore Rose David (1944, p. 28), they will only be discussed very briefly herein (Text-fig. 4a,b). Figure 4a illustrates diagrammatically the different parts of a teleostean

---

EXPLANATION OF PLATE 139

FIG. *1*—*Uvigerina modeloensis* Cushman & Kleinpell, ×31; a, side view; b, apertural view; hypotype, USC No. 3573.

2—*Uvigerina senticosa* Cushman, ×33; a, side view; b, apertural view; hypotype, USC No. 3574.

3—*Uvigerina rothwelli* Pierce, n. sp., ×24; a, side view; b, apertural view; holotype, USC No. 3575.

4—*Uvigerina subperegrina* Cushman & Kleinpell, ×23; a, side view; b, apertural view; hypotype, USC No. 3576.

5—*Angulogerina occidentalis* Cushman, ×52; a, side view; b, apertural view; hypotype, USC No. 3577.

6—*Siphonodosaria advena* (Cushman & Laiming), ×32; a, side view; b, apertural view; hypotype, USC No. 3578.

7—*Siphonodosaria irregularis* (Kleinpell), ×34; a, side view; b, apertural view; hypotype, USC No. 3579.

8—*Cassidulina barbarana* Cushman & Kleinpell, ×69; a, side view; b, apertural view; hypotype, USC No. 3580.

9—*Cassidulina modeloensis* Rankin, ×27; a, side view; b, apertural view; hypotype, USC No. 3581.

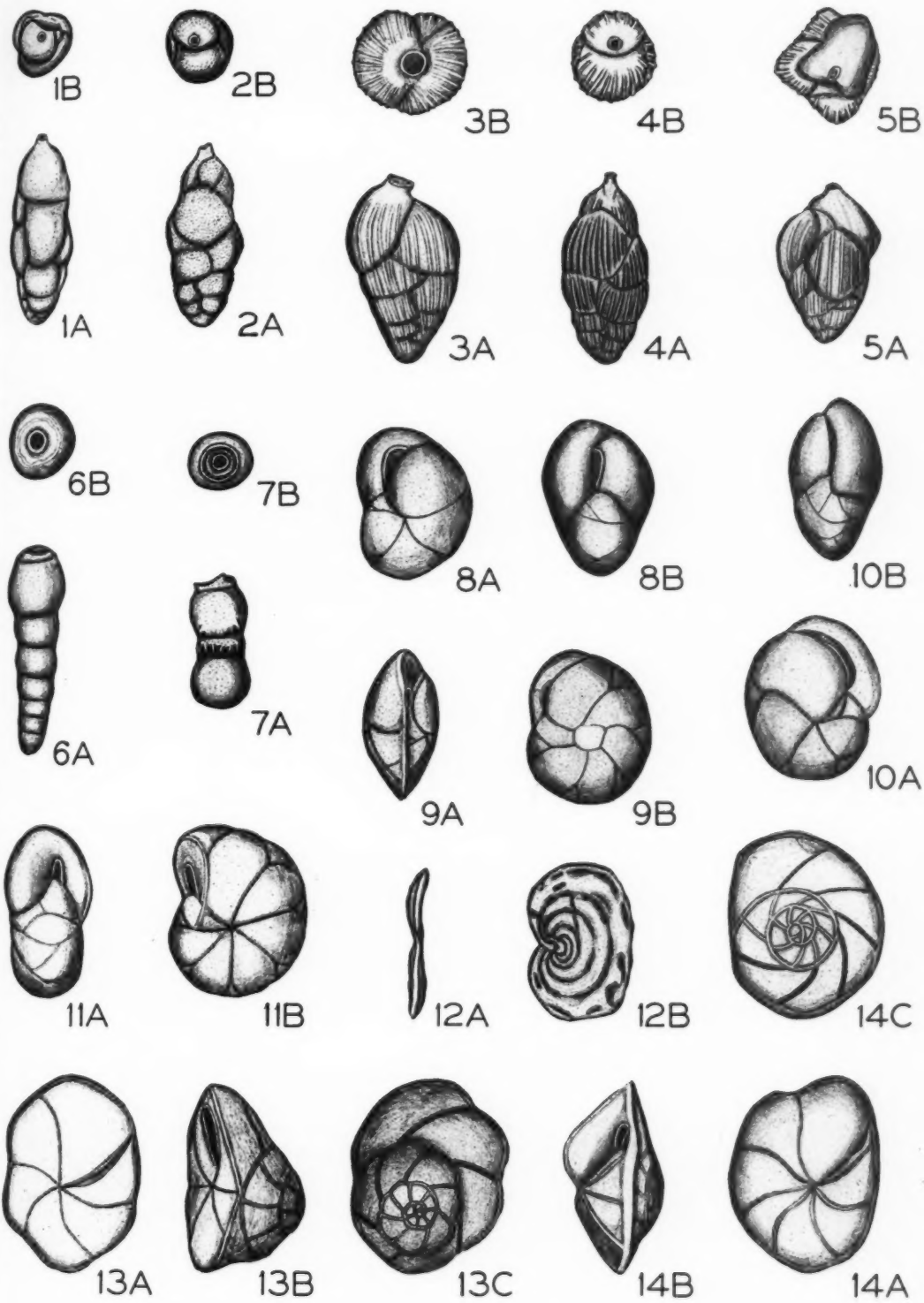
10—*Cassidulina delicata* Cushman, ×78; a, side view; b, apertural view; hypotype, USC No. 3582.

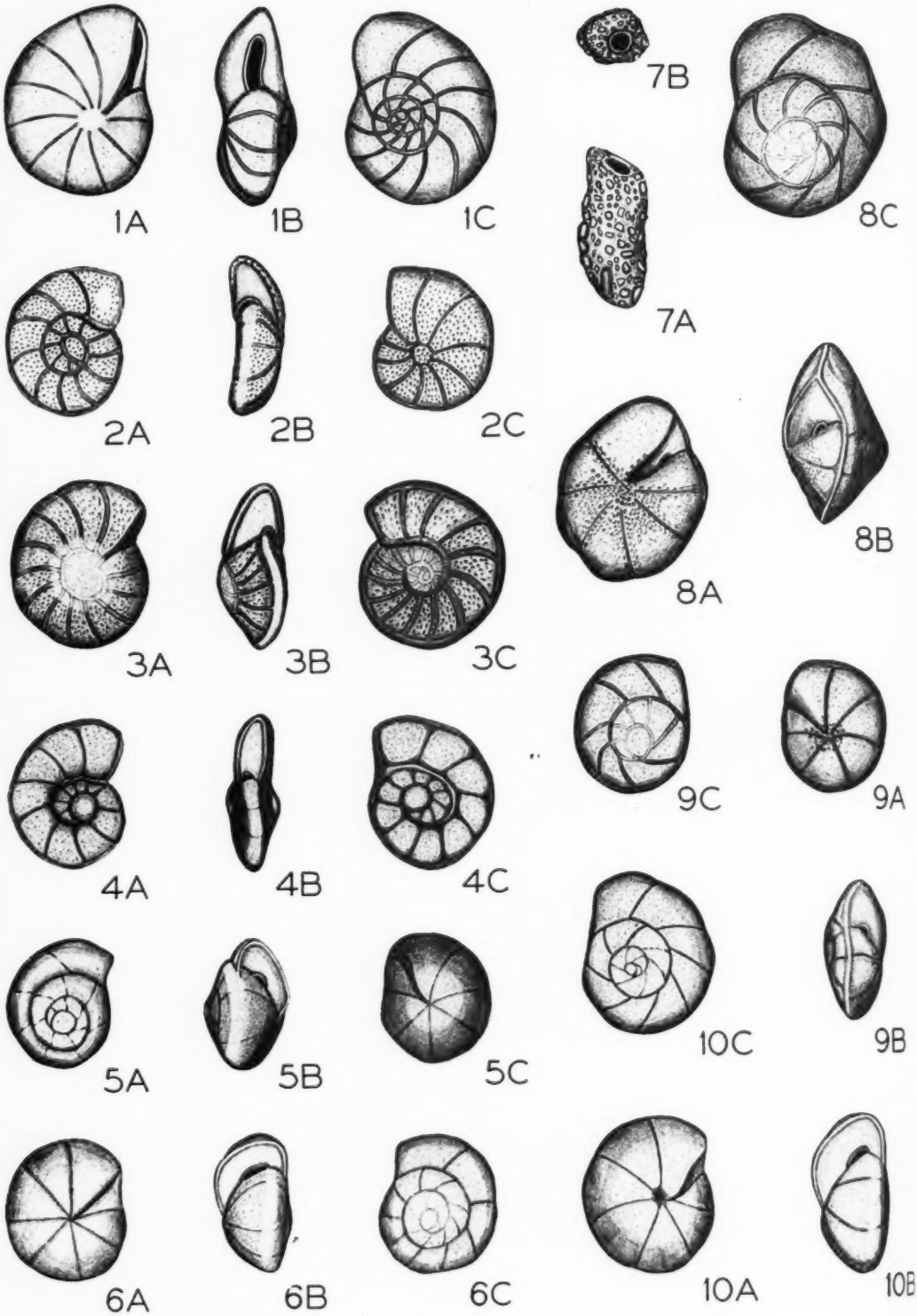
11—*Cassidulina panzana* Kleinpell, ×46; a, side view; b, apertural view; hypotype, USC No. 3583.

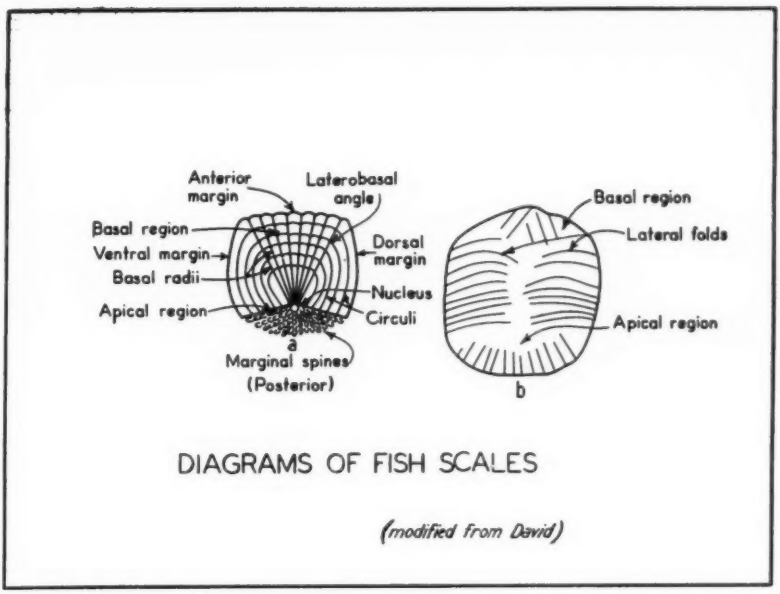
12—*Cassidulinella renulinaformis* Natland, ×16; a, side view; b, apertural view; hypotype, USC No. 3584.

13—*Epistominella discorbisoides* Pierce, n. sp., ×78; a, ventral view; b, apertural view; c, dorsal view; holotype, USC No. 3585.

14—*Epistominella smithi* R. E. & K. C. Stewart, ×74; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3586.


1B
2B
3B
4B
5B
1A
2A
3A
4A
5A
6B
7B
8A
8B
10B
6A
7A
9A
9B
10A
11A
11B
12A
12B
14C
13A
13B
13C
14B
14A


1A
1B
1C
7B
8C
7A
2A
2B
2C
8B
8A
3A
3B
3C
9C
9A
4A
4B
4C
10C
9B
5A
5B
5C
6A
6B
6C
10A
10B



TEXT-FIG. 4

fish scale (much like that of a Lompoquia fish scale). The greater part of the scale is covered by fine lines, called circuli, which may be circular, take different directions toward the margin of the scale, or form a strong laterobasal angle. The point of convergence of the circuli is called the nucleus. Posterior to the nucleus is the apical part of the scale, which may be free from circuli and may be with or without marginal spines. The apical part of the scale projects out into the water and toward the tail of the fish. Anterior to the nucleus is the basal region where the scale is attached to the fish and may have strongly folded basal radii. Basal radii are lines that project at different angles

---

EXPLANATION OF PLATE 140

FIG. *1*—*Epistominella subperuviana* Cushman, ×74; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3587.

2—*Cibicides fletcheri* Galloway & Wissler, ×57; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3589.

3—*Anomalina schmitti* Cushman & Wickenden, ×58; a, ventral view; b, apertural view; hypotype, USC No. 3590.

4—*Rotalia garveyensis* Natland, ×57; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3591.

5—*Eponides healdi* R. E. & K. C. Stewart, ×36; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3594.

6—*Gyroidina keenani* (Cushman & Kleinpell), ×62; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3595.

7—*Bathysiphon arenacea* Cushman, ×15; a, side view; b, apertural view; hypotype, USC No. 3588.

8—*Buccella frigida* (Cushman), ×87; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3592.

9—*Buccella mansfieldi* (Cushman), ×50; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3593.

10—*Gyroidina keenani* (Cushman & Kleinpell) var. *murietta* Pierce, n. var., ×69; a, ventral view; b, apertural view; c, dorsal view; holotype, USC No. 3596.

from the nucleus toward the anterior part of the scale. The laterobasal angle is the angle formed by the circuli meeting the basal radii. Text-figure *4b*, illustrates a clupeoid scale which is in strong contrast to *4a*, in that it has traverse radii or lateral folds instead of basal radii.

Other miscellaneous observations

Observations of the bedding planes of the samples also revealed: large numbers of crushed *Bulimina* sp. and *Bathysiphon* sp. throughout most of the Modelo; literally floods of entire and broken frustules of diatoms, spicules of sponges, Radiolaria, and small, round or oblong bodies, possible sponge globules throughout the Mohnian; and *Pecten* (*Pseudamusium*) *peckhami* which was the only megafossil found in the Modelo at this locality.

PALEOECOLOGY

In order to reconstruct the Mohnian ecologic conditions of the Modelo, it is necessary to compare Mohnian and Recent faunas, preferably of the same province. Both Natland's (1933, p. 227–228) and Bandy's (1953, p. 172) contributions to the ecology of Foraminifera provide, directly and indirectly, a means for determining past conditions.

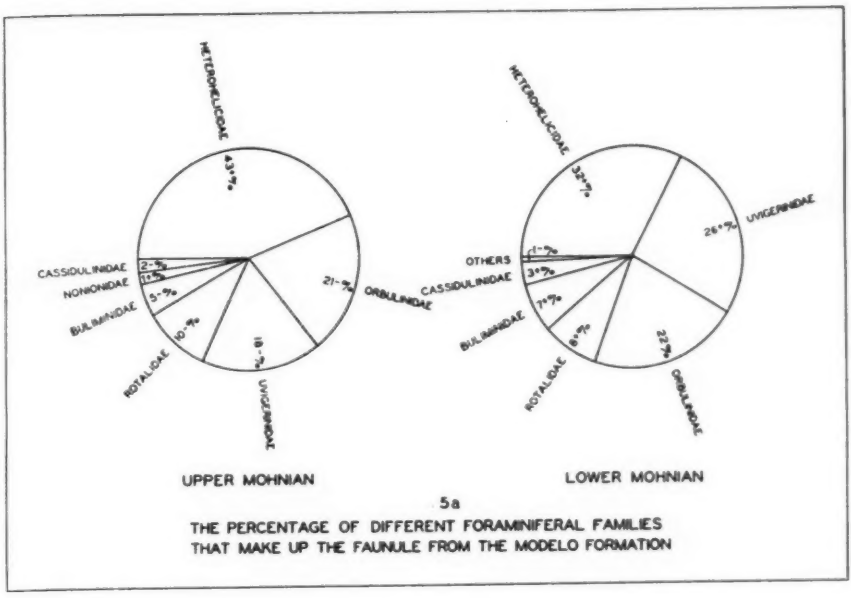
Text-figure *5a* shows the percentages of the different families that make up the faunule from the Modelo formation. From these percentages one can see that the two most abundant benthonic families are the *Heterohelicidae* and the *Uvigerinidae*. The former, *Heterohelicidae*, is represented by *Bolivina*, which is the most predominant genus occurring in both upper and lower Mohnian (43% and 32% respectively). The latter family, *Uvigerinidae*, consists almost entirely of *Uvigerina subperegrina* and *Uvigerina hootsi*, which are characteristically found, locally in both upper and lower Mohnian sediments (18% and 26% respectively). The most abundant benthonic species for the Mohnian part of the Modelo is *Uvigerina subperegrina*. The remainder of the faunule for upper and lower Mohnian is composed of 21 and 22 percent *Orbulinidae*, 10 and 8 percent *Rotalidae*, 5 and 7 percent *Buliminidae*, 2 and 3 percent *Cassidulinidae*, 1 percent *Nonionidae* (upper Mohnian) and 1 percent of other families (lower Mohnian) (Text-fig. 5a).

Because of the absence of lagoonal and littoral foraminiferal species, minority percentage of neritic species and the predominate percentage of *Bolivina* and *Uvigerina*, which characterize Natland's zone IV (900–6500′) and Bandy's bathyal zone (600–6000′), the Mohnian sediments of Benedict Canyon were probably deposited within bathyal depths (Text-fig. 6a,b).

It is interesting to note that Lowman (1949, p. 1954–55) has presented a generic depth-distribution chart of Recent Gulf of Mexico Foraminifera, in which he has erected a number of faunal associations. Lowman found that *Bolivina* and *Uvigerina* were especially characteristic of the upper bathyal depths.

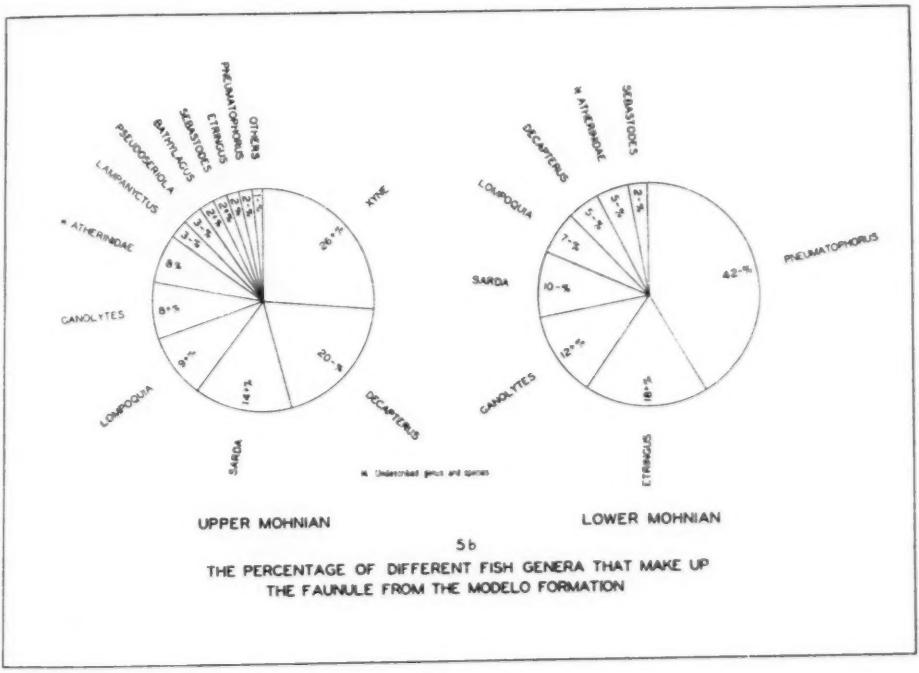
This hypothesis, that the Mohnian sediments of Benedict Canyon were probably deposited in bathyal depths, is further supported by the presence of certain fossil fish scales and fish skeletons that occur in upper Mohnian, such as *Lampanyctus bolini* David, lantern fish; *Bathylagus* (*Quaesita*) *angelensis* (Jordan & Gilbert), a fish skeleton; and *Xyne grex* Jordan & Gilbert (normal herring). The lantern fish are bathypelagic forms, living in water from at least 150 fathoms to considerably greater depths (David, 1944, p. 69). *Bathylagus* (*Quaesita*) *angelensis*, degenerate salmon is also a bathypelagic fish which normally lives beyond the 100 fathom line (David, 1944, p. 59). *Xyne grex* (normal herring) and herring-like fish come toward shore in large schools to spawn but live in deep water the remainder of the year (David, 1944, p. 76) (Text-fig. 6a).

Of the total number of fish scales present in the lower Mohnian, over 50 percent consist of *Sarda stockii* (bonito) and *Pneumatophorus* cf. *P. grex* (chub mackerel, tinker mackerel), which are oceanic fish and suggest great distances from shore (Text-fig. 5b and 6b). Neritic species of fish are well represented in both upper and lower Mohnian parts of the Modelo. Oceanic fish such as *Sarda stockii* and *Pneumatophorus* cf. *P. grex*, occurring with such neritic fauna as *Etringus* (round herring), *Lompoquia* (silver perch), *Atherinidae* (smelts), *Sebastodes* (rock fish) and *Ganolytes* (shad), can be ex-



5a

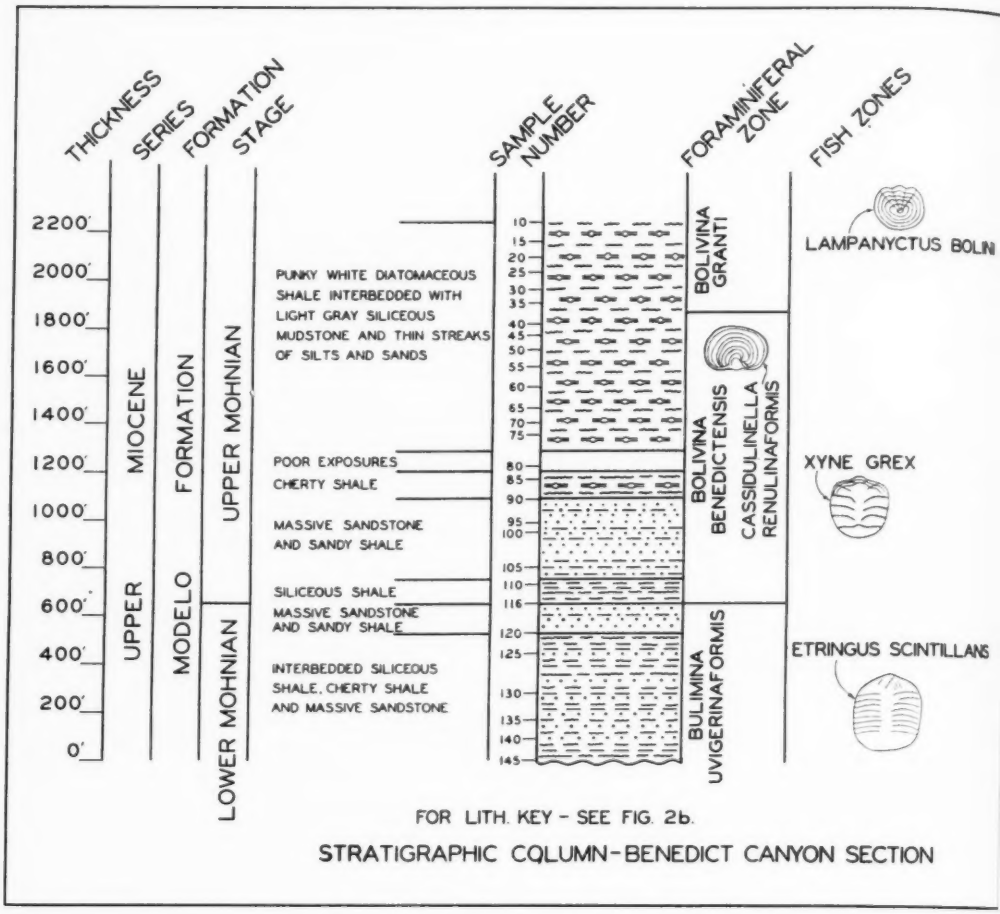
THE PERCENTAGE OF DIFFERENT FORAMINIFERAL FAMILIES THAT MAKE UP THE FAUNULE FROM THE MODELO FORMATION



5b

THE PERCENTAGE OF DIFFERENT FISH GENERA THAT MAKE UP THE FAUNULE FROM THE MODELO FORMATION

TEXT-FIG. 5



TEXT-FIG. 6

plained by an accumulation of their remains at the bottom of a steeply inclined continental slope near a shoal area. Here, species of the bathypelagic zone mingled with the deepest neritic fishes of the coastal banks or with the dead specimens that drifted into this region from the neritic waters.

From the study of fish in sediments near Benedict Canyon, it appears that there was a gradual deepening within the bathyal zone, from lower Mohnian to upper Mohnian time. Evidence of the above is the greater number of bathyal fish species (not the percentages of fish scales), such as *Lampanyctus bolini* and *Bathylagus* (*Quaesita*) *angelensis*, that occur in upper Mohnian sediments (Text-fig. 6a,b). Perhaps this is also reflected in the 11 percent increase in the *Heterohelicidae*, when comparing percentages of lower Mohnian faunas to upper Mohnian faunas (32 to 43 percent, respectively).

CONCLUSIONS

1. In the Benedict Canyon section, Mohnian fish markers afford age determinations when the sediments are barren of Foraminifera or when the latter have been crushed beyond identification. When Mohnian foraminiferal markers are not present, the Mohnian fish markers sometimes give a more accurate correlation than Foraminifera.

2. The Mohnian part of the Modelo formation at Benedict Canyon may be sub-

divided into three zones by both Foraminifera and fish, in the following descending order:

Foraminferal zones	Fish zones
Bolivina granti	*Lampanyctus bolini* *Bathylagus* (*Quaesita*) *angelensis*
Bolivina benedictensis *Cassidulinella renulinaformis*	*Xyne grex*
Bulimina uvigerinaformis	*Etringus scintillans*

3. Fish serve as a satisfactory check on the ecology of Foraminifera because most fishes are restricted to certain environments as regards to temperature, depth, and salinity; and, therefore, they can be assigned easily to their abyssal, bathyal, neritic, or littoral habitat. Because most fishes are good swimmers they are less likely to be trapped in an undesirable environment than are the slow moving Foraminifera and, thus, fish, when abundant could give a better ecological picture of the past conditions than could Foraminifera.

4. From the results of the fish study herein of Benedict Canyon it is possible to recognize a gradual bathymetric increase during the Mohnian stage.

FAUNAL REFERENCE LIST

Listed below are the species of Foraminifera and fish used in making up the stratigraphic distribution of Table 1. After each species is given the original reference and another reference to the plate and figures in this paper.

FORAMINIFERA

Allomorphina trochoides (Reuss), 1845, Verstein bohm, pt. 1, p. 36, pl. 12, fig. 22.
(Pl. 138, fig. 1)

Angulogerina occidentalis (Cushman), 1923, U. S. Nat. Mus. Bull., 104, pt. 4, p. 169, pl. 5, fig. 3,4.
(Pl. 139, fig. 5)

Anomalina schmitti Cushman & Wickenden, 1929, U. S. Nat. Mus. Proc., 2780, vol. 75, art. 9, p. 14, pl. 6, fig. 5.
(Pl. 140, fig. 3)

Bathysiphon arenaceous Cushman, 1927, Scripps Inst. Oceanography Bull., Tech. ser., vol. 1, p. 129, pl. 1, fig. 2.
(Pl. 140, fig. 7)

Bolivina barbarana Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 11, pl. 2, fig. 5.
(Pl. 142, fig. 8)

Bolivina benedictensis Pierce, n. sp. (Pl. 142, fig. 9).

Bolivina bramlettei Kleinpell, 1938, Miocene Stratigraphy of California, p. 267, pl. 21, fig. 9,10,11.
(Pl. 142, fig. 10)

Bolivina brevior Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 31, 32, pl. 5, fig. 8.
(Pl. 142, fig. 11)

Bolivina californica Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 32, pl. 5, fig. 10.
(Pl. 142, fig. 12)

Bolivina davisi Cushman & Ellisor, 1945, Jour. Paleontology, vol. 19, p. 565, pl. 76, fig. 6.
(Pl. 142, fig. 13)

Bolivina decurtata Cushman, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 44, pl. 6, fig. 7. (Pl. 142, fig. 6)

Bolivina girardensis Rankin, 1934, in Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, p. 17, pl. 3, fig. 7.
(Pl. 142, fig. 7)

Bolivina granti Rankin, 1934, in Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, p. 21, pl. 4, fig. 2,3.
(Pl. 143, fig. 1)

Bolivina hughesi Cushman, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 43, 44, pl. 6, fig. 4.
(Pl. 143, fig. 2)

Bolivina marginata Cushman var. *monicana* Pierce, n. var. (Pl. 143, fig. 3).

Bolivina perrini Kleinpell, 1930, Micro. Bull. (mimeographed), vol. 2, no. 2, p. 29.
(Pl. 143, fig. 4)

Bolivina pisciformis Galloway & Morrey, 1929, Bull. Amer. Paleont., vol. 15, no. 55, p. 36, pl. 5, fig. 10.
(Pl. 143, fig. 11)

Bolivina pseudospissa Kleinpell, 1938, Miocene Stratigraphy of California, p. 279, pl. 21, fig. 6.
(Pl. 143, fig. 5)

Bolivina salinasensis Kleinpell, 1938, Miocene Stratigraphy of California, p. 280, pl. 15, fig. 3.
(Pl. 143, fig. 6)

Bolivina seminuda Cushman var. *humilis* Cushman and McCulloch, 1942, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 211, pl. 26, fig. 1–6.
(Pl. 143, fig. 7)

Bolivina sinuata Galloway & Wissler, 1927, Jour. Paleont., vol. 1, p. 71–72, pl. 11, fig. 9.
(Pl. 143, fig. 8)

Bolivina tongi Cushman, 1929, Contr. Cushman Lab. Foram. Res., vol. 5, pt. 4, no. 84, p. 93, pl. 13, fig. 29.
(Pl. 143, fig. 14)

Bolivina tumida Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 32, pl. 5, fig. 9.
(Pl. 143, fig. 9)

Bolivina tumida Cushman var. *cuneata* Kleinpell, Miocene Stratigraphy of California, p. 285, pl. 14, fig. 9.
(Pl. 143, fig. 10)

Bolivina vaughani Natland, 1938, Scripps Inst. Oceanography Bull., Tech. ser., vol. 4, no. 5, p. 146, pl. 5, fig. 11.
(Pl. 143, fig. 13)

Bolivina woodringi Kleinpell, 1938, Miocene Stratigraphy of California, p. 285–286, pl. 21, fig. 4,5.
(Pl. 143, fig. 12)

Buccella frigida (Cushman), 1922, Contr. Canadian Biol., no. 9, p. 144.
(Pl. 140, fig. 8)

Buccella mansfieldi (Cushman), 1931, in Cushman & Parker, Contr. Cushman Lab. Foram. Res., vol. 7, p. 12, pl. 2, fig. 10.
(Pl. 140, fig. 9)

Bulimina ovula d'Orbigny, 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 51, pl. 1, fig. 10,11.
(Pl. 138, fig. 2)

Bulimina pagoda Cushman var. *hebespinata* R. E. & K. C. Stewart, 1930, Jour. Paleont., vol. 4, p. 63, pl. 8, fig. 3.
(Pl. 138, fig. 3)

Bulimina rostrata Brady, 1884, *Challenger* Report, Zoology, vol. 9, p. 408, pl. 51, fig. 14,15.
(Pl. 138, fig. 5)

Bulimina uvigerinaformis Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 5, pl. 1, fig. 14.
(Pl. 138, fig. 4,10)

Buliminella brevior Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 33, pl. 5, fig. 14.
(Pl. 138, fig. 9)

Buliminella curta Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 33, pl. 5, fig. 13.
(Pl. 138, fig. 11)

Buliminella madagascarensis (d'Orbigny), 1826, Royal Acad. Sci. Inst. Bologna, Mem. Sci. Nat. ser. 6, tomo 5, p. 47, pl. 1, fig. 13.
(Pl. 138, fig. 12)

Buliminella semihispida Kleinpell, 1938, Miocene Stratigraphy of California, p. 250, pl. 20, fig. 8,15,16.
(Pl. 138, fig. 13)

Buliminella subfusiformis Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 33, pl. 5, fig. 12.
(Pl. 138, fig. 14)

Cassidulina barbarana Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 16, pl. 3, fig. 5.
(Pl. 139, fig. 8)

Cassidulina delicata Cushman, 1927, Scripps Inst. Oceanography Bull., Tech. ser., vol. 1, no. 10, p. 168, pl. 6, fig. 5.
(Pl. 139, fig. 10)

Cassidulina modeloensis Rankin, 1934, in Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol., 10, p. 23, pl. 3, fig. 12.
(Pl. 139, fig. 9)

Cassidulina panzana Kleinpell, 1938, Miocene Stratigraphy of California, p. 335, pl. 8, fig. 9.
(Pl. 139, fig. 11)

Cassidulinella renulinaformis Natland, 1940, Jour. Paleont., vol. 14, p. 571, pl. 69, fig. 1,4,7.
(Pl. 139, fig. 12)

Cibicides fletcheri Galloway & Wissler, 1927, Jour. Paleont., vol. 1, p. 64, pl. 10, fig. 8,9.
(Pl. 140, fig. 2)

Dentalina cf. *D. barnesi* Rankin, 1934, in Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, p. 17, pl. 3, fig. 6.
(Pl. 137, fig. 2)

Dentalina monicana Pierce, n. sp. (Pl. 137, fig. 3).

Discorbinella valmonteensis Kleinpell, 1938, Miocene Stratigraphy of California, p. 350-351, pl, 21, fig. 14,15.
(Pl. 142, fig. 3)

Elphidium granti Kleinpell, 1938, Miocene Stratigraphy of California, p. 238, pl. 19, fig. 1,11.
(Pl. 137, fig. 14)

Epistominella discorbisoides Pierce, n. sp. (Pl. 139, fig. 13).

Epistominella smithi (R. E. & K. C. Stewart), 1930, Jour. Paleont., vol. 4, p. 70, pl. 9, fig. 4.
(Pl. 139, fig. 14)

Epistominella subperuviana (Cushman), 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 63, pl. 9, fig. 9.
(Pl. 140, fig. 1)

Eponides healdi R. E. & K. C. Stewart, 1930, Jour. Paleont., vol. 4, p. 70, pl. 8, fig. 8.
(Pl. 140, fig. 5)

Fissurina tricostulata Pierce, n. sp. (Pl. 137, fig. 7).

Frondicularia sp. (Pl. 137, fig. 4).

Globigerina bulloides d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, tome 7, p. 277, mod. 17. 76.
(Pl. 142, fig. 4)

Globobulimina pacifica Cushman, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, no. 39, p. 67, pl. 14, fig. 12.
(Pl. 138, fig. 6)

Globorotalia canariensis (d'Orbigny), 1839, in Barker, Webb & Berthelot, Hist. Nat. des Iles Canaries, vol. 2, pt. 2, p. 130, pl. 1, fig. 34–36.
(Pl. 141, fig. 6)

Globorotalia scitula (Brady), 1882, Royal Soc. Edinburgh Proc., vol. 11, p. 716.
(Pl. 141, fig. 7)

Gyroidina keenani (Cushman & Kleinpell), 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 14, pl. 3, fig. 10,11.
(Pl. 140, fig. 6)

Gyroidina keenani (Cushman & Kleinpell) var. *murietta* Pierce, n. var. (Pl. 140, fig. 10).

Gyroidina multicamerata (Kleinpell), 1938,

Miocene Stratigraphy of California, p. 320, pl. 19, fig. 2,3,7.
(Pl. 141, fig. 1)

Gyroidina soldanii d'Orbigny var. *rotundimargo* R. E. & K. C. Stewart, 1930, Jour. Paleont., vol. 4, p. 58, pl. 9, fig. 3.
(Pl. 141, fig. 2)

Hanzawaia illingi (Nuttall), 1928, Quart. Jour. Geol. Soc., vol. 84, pt. 1, p. 97–98, pl. 7, fig. 11,17.
(Pl. 142, fig. 1)

Lagena scalariformis (Williamson), 1858, On the Recent Foraminifera of Great Britain, Royal Society, London, p. 13, pl. 1, fig. 30.
(Pl. 137, fig. 5)

Lagena striato-punctata Parker & Jones var. *pentacosta* Pierce n. var. (Pl. 137, fig. 6).

Nodosaria tympaniplectiformis Schwager, 1866, Novara Exped., Geol. Theil., vol. 2, pl. 5, fig. 34.
(Pl. 137, fig. 1)

Nonion goudkoffi Kleinpell, 1938, Miocene Stratigraphy of California, p. 231, pl. 20, fig. 2,5.
(Pl. 137, fig. 8)

Nonionella belridgensis (Barbat & Johnson), 1934), Jour. Paleont., vol. 8, no. 1, p. 11, pl. 1, fig. 8,9.
(Pl. 137, fig. 9)

Nonionella davanaensis Pierce, n. sp. (Pl. 137, fig. 10).

Orbulina universa d'Orbigny, 1839, in De la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, vol. 8, p. 2, pl. 1, fig. 1.
(Pl. 142, fig. 5)

Planulina ornata (d'Orbigny), 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 40, pl. 6, fig. 7,9.
(Pl. 142, fig. 2)

Pullenia cf. *P. miocenica* Kleinpell, 1938, Miocene Stratigraphy of California, p. 338, pl. 14, fig. 6.
(Pl. 137, fig. 12)

Pullenia salisburyi R. E. & K. C. Stewart, 1931, Contr. Cushman Lab. Foram. Res., vol. 7, pt. 1, p. 15, pl. 2, fig. 15a,b.
(Pl. 137, fig. 11)

Rotalia garveyensis Natland, 1938, Scripps Inst. Oceanography Bull., Tech. ser., vol. 4, no. 5, p. 147, pl. 6, fig. 6.
(Pl. 140, fig. 4)

Siphonodosaria advena (Cushman & Laiming), 1931, Jour. Paleont., vol. 5, no. 2, p. 106, pl. 11, fig. 19.
(Pl. 139, fig. 6)

Siphonodosaria irregularis (Kleinpell), 1938, Miocene Stratigraphy of California, p. 245, pl. 17, fig. 12.
(Pl. 139, fig. 7)

Sphaeroidina bulloides d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, tome 7, p. 267, modeles, no. 65, zme livraison.
(Pl. 137, fig. 13)

Suggrunda californica Kleinpell, 1938, Miocene Stratigraphy of California, p. 287, pl. 18, fig. 8,9,10.
(Pl. 143, fig. 15)

Suggrunda kleinpelli Bramlette, U. S. Geol. Survey Prof. Paper 222, p. 59, pl. 23, fig. 4,5,9.
(Pl. 143, fig. 16)

Uvigerina hootsi Rankin, 1934, in Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, pt. 1, p. 22, pl. 3, fig. 8,9.
(Pl. 138, fig. 15)

Uvigerina modeloensis Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 12, pl. 2, fig. 8.
(Pl. 139, fig. 1)

Uvigerina senticosa Cushman, 1927, Scripps Inst. Oceanography Bull., Tech. ser., vol. 1, p. 159, pl. 3, fig. 14.
(Pl. 139, fig. 2)

Uvigerina rothwelli Pierce, n. sp. (Pl. 139, fig. 3).

Uvigerina subperegrina Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 12, pl. 2, fig. 9,11.
(Pl. 139, fig. 4)

Valvulineria alicia Pierce, n. sp. (Pl. 141, fig. 3,5,9).

Valvulineria araucana (d'Orbigny) var. *malagaensis* Kleinpell, 1938, Miocene Stratigraphy of California, p. 308, pl. 22, fig. 10,11,12.
(Pl. 141, fig. 8)

Valvulineria californica Cushman var. *obesa* Cushman, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 61, pl. 9, fig. 2.
(Pl. 141, fig. 4)

Virgulina californiensis Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol., 1. p. 32, pl. 5, fig. 11.
(Pl. 138, fig. 7)

Virgulina californiensis Cushman var. *grandis* Cushman & Kleinpell, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 9, pl. 1, fig. 15,16.
(Pl. 138, fig. 8)

FISH

Atherinindae no. 1 David, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 48, pl. 4, no. 48a, pl. 6, no. 3a.
(Pl. 144, fig. 13)

Atherinidae no. 2 David, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 39, pl. 4, no. 33.
(Pl. 144, fig. 16)

Atherinidae no. 4 David, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 41, pl. 5, no. 49.
(Pl. 144, fig. 17)

Bathylagus (*Quaesita*) *angelensis* (Jordan & Gilbert), 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 32, pl. 15.
(Pl. 144, fig. 5)

Decapterus (*Lompochites*) cf. *D. hopkinsi* (Jordan & Gilbert), Fossil fishes of diatom beds of Lompoc, California, Stanford Univ. Publ., p. 30, pl. 20.
(Pl. 144, fig. 8)

Etringus scintillans Jordan, 1907, Univ. of

Calif. Publ., Geol. Sci., vol. 5, p. 121, fig. 17,20.
(Pl. 144, fig. 4)

Canolytes aratus (Jordan), 1924, Southern Calif. Acad. Sci. Bull., vol. 23, p. 42, pl. F.
(Pl. 144, fig. 2)

Ganolytes cf. *G. cameo* Jordan, 1919, Fossil fishes of Southern California, Stanford Univ. Publ., p. 6, pl. 2,4.
(Pl. 144, fig. 3)

Lampanyctus bolini David, 1943, Geol. Soc. Amer., Sp. Pap. no. 43, p. 64–65, pl. 7, fig. 2, pl. 9, fig. 1,2.
(Pl. 144, fig. 6,7)

Lompoquia culveri (Jordan), 1925, The fossil fishes of the Miocene of California, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 23, pl. 10.
(Pl. 144, fig. 11)

Lompoquia retropes Jordan & Gilbert, 1919, Fossil fishes of Southern California, p. 44, pl. 24.
(Pl. 144, fig. 9)

Pneumatophorus cf. *P. grex* (Mitchell), 1943, in David, Geol. Soc. Amer., Sp. Pap. no. 43, p. 151.
(Pl. 144, fig. 12)

Pseudoseriola sp. David, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 41, pl. 5, no. 44.
(Pl. 144, fig. 14)

Sarda cf. *S. stockii* David, 1943, Geol. Soc. Amer., Sp. Pap. no. 43, p. 31–33, pl. 4.
(Pl. 144, fig. 10)

Sebastodes aff. *S. elongatus* Ayres, 1943, in David, Geol. Soc. Amer., Sp. Pap. no. 43, p. 163.
(Pl. 144, fig. 15)

Xyne grex Jordan & Gilbert, 1919, Fossil fishes of Southern California, Stanford Univ. Publ., p. 25.
(Pl. 144, fig. 1)

SYSTEMATIC PALEONTOLOGY

In making the frequency distribution studies of the Foraminifera and fish of the Modelo formation in Benedict Canyon, Sherman Oaks, California, the writer encountered several undescribed foraminiferal species and varieties and several taxonomic problems. These new forms are described and figured herein with a brief discussion of the taxonomic problems involved in this study. The type specimens are deposited in the paleontological collections at the University of Southern California. Because very little work has been done in describing fossil fish scales, the author has used a modified form of T. D. A. Cockerell (1919, p. 171–188). The fish scales figured herein are oriented with the apical end toward the viewer, which is just the opposite of that figured by T. D. A. Cockerell.

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERA
Family NODOSARIIDAE Schultze, 1839
Genus DENTALINA d'Orbigny, 1839
DENTALINA MONICANA Pierce, n. sp.
Pl. 137, fig. 3

Test elongate, medium size, initial end rounded; chambers uniserial, slightly inflated; sutures nearly transverse, slightly oblique in the early portion, narrowly limbate; wall finely perforated, ornamented by about 6 to 8 longitudinal costae with some being continuous across the sutures and others discontinuous; apertural end broken in this specimen, terminal, central and radiate. Length, 0.75 mm.; diameter, 0.23 mm. Rare.

It differs from *Dentalina pioneerensis* Kleinpell in that the costae do not fuse together to form a spine on the initial end, test curves and sutures are more narrowly limbate. This specimen differs from *Dentalina quadrulata* Cushman and Laiming in that the test has 6 or more distinct angles and the chambers being more inflated.

Holotype.—USC No. 3547.

Genus LAGENA Walker & Boys, 1784
LAGENA STRIATO-PUNCTATA Parker & Jones var. PENTACOSTA Pierce, n. var.
Pl. 137, fig. 6

Test unilocular, slender, circular in cross section, short slender neck; wall ornamented with five raised longitudinal perforated costae extending the entire length of test nearly equally spaced on the surface of the test; aperture terminal, round. Length, 0.35 mm.; diameter, 0.18 mm. Rare.

This variety differs from *Lagena striato-punctata* Parker & Jones var. *tricosta* Cushman & Gray in having five prominent, raised, perforated, longitudinal costae instead of three longitudinal costae.

Holotype.—USC No. 3550.

Genus FISSURINA Reuss, 1850
FISSURINA TRICOSTULATA Pierce, n. sp.
Pl. 137, fig. 7

Test unilocular, pyriform, elliptical in cross section about the middle, length about

1⅓ times as long as wide, in side view slightly tapering towards the apertural end; wall thin, finely perforated, on each face an inner raised elliptical ridge running continuously within the margin of the test and connecting the aperture on the lateral sides; aperture fissurine, elliptical, parallel with keel. Length, 0.32 mm.; breadth, 0.25 mm.; thickness, 0.18 mm. Rare.

This species is very similar to *Fissurina orbignyana* (Sequenza) var. *elliptica* (Cushman) but differs in having on each face of the chamber an inner raised elliptical ridge giving the appearance of 3 costae on each lateral side of the aperture in the apertural view.

Holotype.—USC No. 3551.

Family NONIONIDAE Reuss, 1860
Genus NONIONELLA Cushman, 1926
NONIONELLA BELRIDGENSIS (Barbat & Johnson)
Pl. 137, fig. 9

Nonion belridgensis BARBAT & JOHNSON, 1934, Jour. Paleont., vol. 8, p. 11, pl. 1, fig. 8,9.
Nonion belridgensis KLEINPELL, 1938, Miocene Stratigraphy of California, p. 229 (Contains prior synonymy).

Test planispiral, longer than broad, slightly umbilicate, periphery acute to subacute, evolute on dorsal side and nearly evolute on ventral side; chambers 9 to 11 in the last whorl, appressed, the last few chambers on ventral side cover part of the earlier chambers, increasing uniformly in size as added; sutures radial, curving, flush near the periphery, slightly depressed near umbilicus; wall smooth, finely perforate; aperture a low arched opening at the base of the last chamber, apertural face heart-shaped. Length, 0.50 mm.; thickness, 0.25 mm.

Because the last few chambers on the ventral side extend somewhat into the umbilicus and cover part of the earlier chambers, the writer has placed this species in the genus *Nonionella*.

Hypotype.—USC No. 3553.

NONIONELLA DAVANAENSIS Pierce, n. sp.
Pl. 137, fig. 10

Test subcircular, about 1½ times as long as broad, edge rounded, periphery slightly lobulate throughout in side view, dorsal side nearly evolute, umbonate, ventral side involute with a narrow, raised, lobate extension of the last chamber covering the umbilicus, back becoming more broadly rounded in the latter part of the last whorl; chambers rather strongly inflated especially in the latter ones, 6 and 7 in the last whorl, increasing in size very gradually as added; sutures depressed, curving; wall smooth, finely perforate; apertural face roughly heart-shaped, aperture a narrow arched opening at the base of the last chamber. Diameter, 0.47 mm.; thickness, 0.29 mm. Present.

It differs from *Nonionella robusta* Plummer in having fewer chambers, umbilical area being filled only by the last chamber on the ventral side, test broader in apertural view and more umbonate on the partial involute side. This new species is named from the Davana Fire Road where many of the samples were taken.

Holotype.—USC No. 3554.

Family UVIGERINIDAE Galloway & Wissler, 1927
Genus UVIGERINA d'Orbigny, 1826
UVIGERINA ROTHWELLI Pierce, n. sp.
Pl. 139, fig. 3

Test elongate, fusiform, about 1½ to 2 times as long as broad, stout, tapering towards the initial end, apertural end very broadly rounded, initial end bluntly pointed, edge slightly lobulate in side view; chambers distinct, triserial, early ones overlapping, increasing rapidly in size as added, somewhat inflated; sutures depressed, slightly curving; wall with numerous fine, low, close set, longitudinal costae which continue across suture lines; aperture terminal, large, round at the end of a short neck with a very slight lip. Length, 1.13 mm.; diameter, 0.63 mm. Rare.

This species is very similar to *Uvigerina quisqueyana* Bermudez but differs in that its longitudinal costae continue across all the sutures and the diameter of the apertural opening being much larger in proportion to the size of the test. This new species was named in honor of W. T. Rothwell, Jr., division paleontologist of Richfield Oil Corporation.

Holotype.—USC No. 3575.

Family ROTALIIDAE Reuss, 1860
Genus EPISTOMINELIA Husezima & Maruhasi, 1944
EPISTOMINELLA DISCORBISOIDES
Pierce, n. sp.
Pl. 139, fig. 13

Test trochoid, dorsal side strongly convex, ventral side flattened, edge keeled, periphery lobulate; chambers distinct, 6 to 8 in the last formed whorl, increasing in size uniformly; sutures obliquely curved on ventral side, nearly radial on dorsal side, slightly depressed and limbate; wall smooth, finely perforate; aperture elongate, narrow, nearly parallel to periphery and to the plane of coiling, ventral. Diameter, 0.37 mm.; thickness, 0.30 mm. Present.

This new species is similar to *Epistominella gyroidinaformis* (Cushman & Goudkoff), 1938, however, the former differs in having a dorsal side strongly convex, ventral side flattened, periphery more lobulate, and fewer chambers.

Holotype.—USC No. 3585.

Genus BUCCELLA Anderson, 1952
BUCCELLA FRIGIDA (Cushman)
Pl. 140, fig. 8

Pulvinulina frigida CUSHMAN, 1922, Contr. Canadian Biol., no. 9, p. 144.
Bucella frigida ANDERSEN, 1952, Wash. Acad. Sci., Jour., vol. 42, no. 5, p. 145, fig. 4–6.
Eponides frigidus BANDY, 1953, Jour. Paleont., vol. 27, no. 2, p. 172, pl. 23, fig. 5.

Test trochoid, nearly biconvex, nearly circular in side view, periphery slightly lobulate, edge acute, slightly keeled on both dorsal and ventral sides; chambers 7 in the last-formed whorl, increasing very gradually in size as added; sutures flush to slightly depressed, narrowly limbate, obliquely curved dorsally, nearly radial ventrally; wall smooth on dorsal side, ventral side with a thick coating of pustules along the ventral sutures, finely perforate; aperture a curved slit at the middle of the septal face of the last chamber, with a slight lip. Diameter, 0.30 mm.; thickness, 0.17 mm. Rare.

This species was placed in the genus *Buccella* because of the thick coating of pustules and accessory apertures along the ventral sutures.

Hypotype.—USC No. 3592.

BUCCELLA MANSFIELDI (Cushman)
Pl. 140, fig. 9

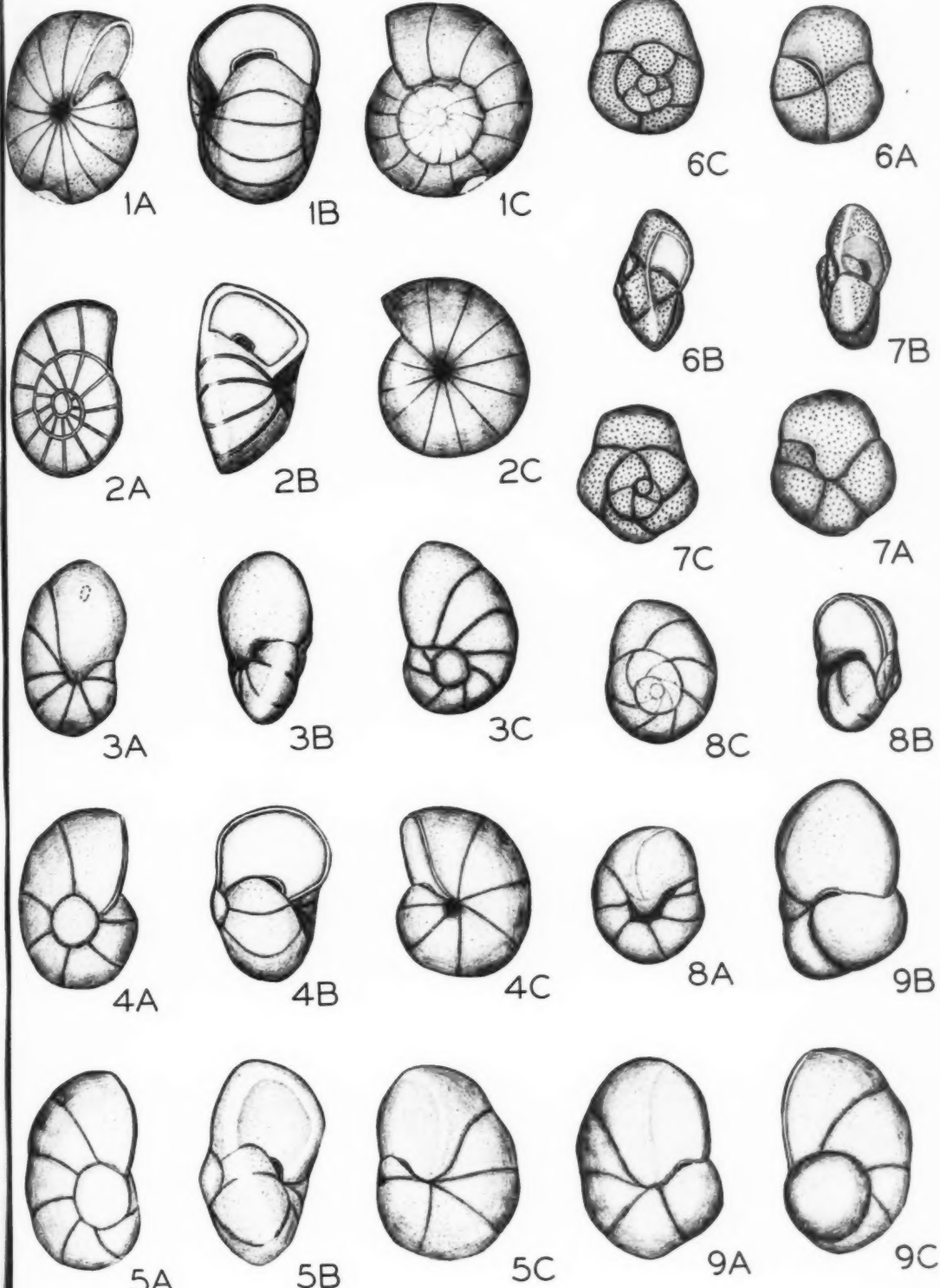
Eponides mansfieldi CUSHMAN, 1931, *in* Cushman & Parker, Contr. Cushman Lab. Foram. Res., vol. 7, p. 12, pl. 2, fig. 10. CUSMAN & BARBAT, 1932, Contr. Cushman Lab. Foram. Res., vol. 8, p. 33. KLEINPELL, 1935, Calif. Oil Fields, vol. 19, no. 2, p. 17–18. KLEIPELL, 1938, Miocene Stratigraphy of California, p. 320, pl. 18, fig. 13,14,15.
Buccella mansfieldi ANDERSEN, 1952, Wash. Acad. Sci., Jour., vol. 42, no. 5, p. 148, fig. 12,13.

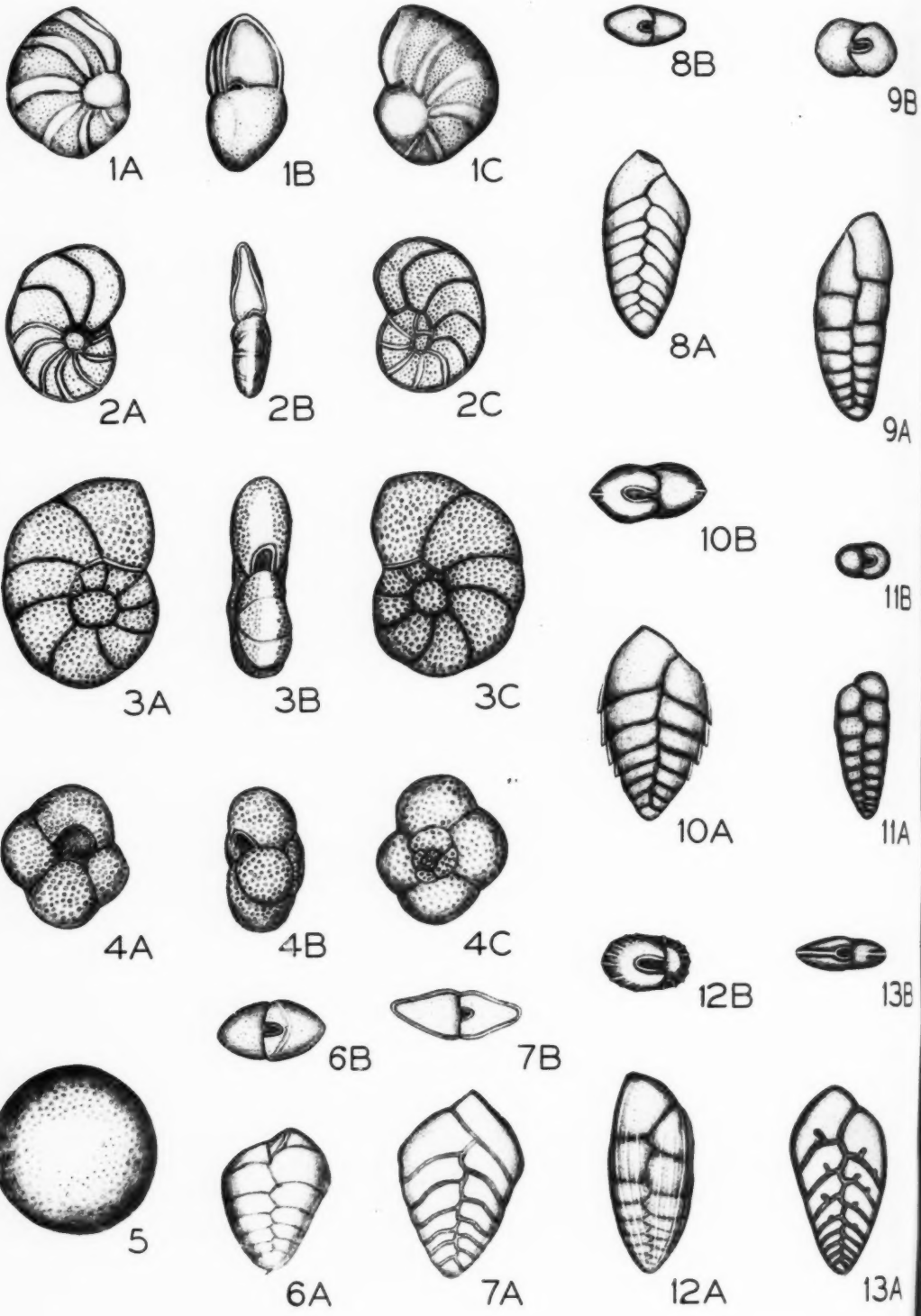
Test trochoid, nearly biconvex, dorsal side somewhat more convex than the ventral side, periphery lobulate, edge acute, keeled; chambers distinct, very slightly inflated on ventral side, about 7 to 8 in the last-formed whorl, increasing gradually as added; sutures narrowly limbate, slightly curved, oblique dorsally, ventrally slightly depressed, nearly radial; wall on the ventral

---

EXPLANATION OF PLATE 141

FIG. *1*—*Gyroidina multicamerata* (Kleinpell), ×50; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3597.
2—*Gyroidina soldanii* d'Orbigny var. *rotundimargo* R. E. & K. C. Stewart, ×62; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3598.
3,5,9—*Valvulineria alicia* Pierce, n. sp., 3, Microspheric, ×45; 3a, ventral view; 3b, apertural view; 3c, dorsal view; 5, Megalospheric, ×83; 5a, dorsal view; 5b, apertural view; 5c, ventral view; 9, Megalospheric, ×83; 9a, ventral view; 9b, apertural view; 9c, dorsal view; holotype, USC No. 3601.
4—*Valvulineria californica* Cushman var. *obesa* Cushman, ×81; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3603.
6—*Globorotalia canariensis* Cushman, ×76; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3599.
7—*Globorotalia scitula* (Brady), ×67; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3600.
8—*Valvulineria araucana* (d'Orbigny) var. *malagaensis* Kleinpell, ×39; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3601.


1A
1B
1C
6C
6A
6B
7B
2A
2B
2C
7C
7A
3A
3B
3C
8C
8B
4A
4B
4C
8A
9B
5A
5B
5C
9A
9C


1A
1B
1C
8B
9B
8A
9A
2A
2B
2C
10B
11B
3A
3B
3C
10A
11A
4A
4B
4C
12B
13B
6B
7B
5
6A
7A
12A
13A

side with a coating of pustules especially in the umbonate area and along the sutures; aperture a curved slit at the middle of the base of the septal face of the last chamber, with a slight lip and accessory apertures along the ventral sutures. Diameter, 0.37 mm.; thickness. 0.25 mm. Rare.

This species was also placed in the genus *Buccella* because of the coating of pustules and accessory apertures along the ventral sutures.

Hypotype.—USC No. 3593.

Genus GYROIDINA D'Orbigny, 1826

GYROIDINA KEENANI (Cushman & Kleinpell)

Pl. 140, fig. 6

Eponides sp. HUGHES & GOUDKOFF, 1931, *in* Hoots, U. S. Geol. Surv. Prof. Paper 165-C, p. 118.

Eponides keenani CUSHMAN & KLEINPELL, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 14, pl. 3, fig. 10,11. WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141,145,147. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 319 (Contains prior synonymy).

Test trochoid, small, nearly circular in side view, periphery broadly rounded and very slightly lobulate, dorsal side somewhat flattened, ventrally convex, edge subacute; chambers fairly distinct, not inflated, increasing in size very gradually, 6 to 8 in the last-formed whorl; sutures flush to slightly depressed, dorsally slightly oblique, nearly straight, narrowly limbate; ventrally nearly radiate; wall smooth, finely perforate; aperture small, low, arched opening midway between the edge and the umbilicus. Diameter, 0.32 mm.; thickness, 0.30 mm. Present to common.

Upon examining the holotype of *Eponides keenani* Cushman and Kleinpell, the writer found that this species had a *Gyroidina*-type aperture and not an *Eponides*-type aperture. Therefore the writer has placed it in the genus, *Gyroidina*.

Hypotype.—USC No. 3595.

GYROIDINA KEENANI (Cushman & Kleinpell) var. MURIETTA Pierce, n. var.

Pl. 140, fig. 10

Test trochoid, small, nearly circular in side view, periphery broadly rounded and very slightly lobulate, dorsal side somewhat flattened, ventrally convex, edge subacute; umbilicus small and deep; chambers fairly distinct, not inflated, increasing in size very gradually, 6 to 8 in the last-formed whorl; sutures flush to slightly depressed, dorsally slightly oblique, nearly straight, narrowly limbate; ventrally nearly radiate; wall

---

EXPLANATION OF PLATE 142

FIG. 1—*Hanzawaia illingi* Nuttall, ×52; a, dorsal view; b, apertural view; c, ventral view; hypotype, USC No. 3605.

2—*Planulina ornata* d'Orbigny, ×45; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3606.

3—*Discorbinella valmonteensis* Kleinpell, ×42; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3609.

4—*Globigerina bulloides* d'Orbigny, ×50; a, ventral view; b, apertural view; c, dorsal view; hypotype, USC No. 3609.

5—*Orbulina universa* d'Orbigny, ×47; hypotype, USC No. 3608.

6—*Bolivina decurata* Cushman, ×41; a, side view; b, apertural view; hypotype, USC No. 3616.

7—*Bolivina girardensis* Rankin, ×63; a, side view; b, apertural view; hypotype, USC No. 3617.

8—*Bolivina barbarana* Cushman & Kleinpell, ×45; a, side view; b, apertural view; hypotype, USC No. 3601.

9—*Bolivina benedictensis* Pierce, n. sp., ×32; a, side view; b, apertural view; holotype, USC No. 3611.

10—*Bolivina bramlettei* Kleinpell, ×65; a, side view; b, apertural view; hypotype, USC No. 3612.

11—*Bolivina brevior* Cushman, ×50; a, side view; b, apertural view; hypotype, USC No. 3613.

12—*Bolivina californica* Cushman, ×44; a, side view; b, apertural view; hypotype, USC No. 3614.

13—*Bolivina davisi* Cushman & Ellisor, ×40; a, side view; b, apertural view; hypotype, USC No. 3615.

smooth, finely perforate; aperture small, low, arched opening midway between the edge and the umbilicus. Diameter, 0.32 mm.; thickness, 0.20 mm. Present.

This variety differs from typical representatives of the species in having a small, deep umbilicus. The above variety was named from Murietta Drive which crosses the line of section of the sampled area.

Holotype.—USC No. 3596.

GYROIDINA MULTICAMERATA (Kleinpell)
Pl. 141, fig. 1

Eponides aff. *E. broeckiana* (Karrer) RANKIN, 1931, *in* Hoots, U. S. Geol. Surv. Prof. Paper 165-C, p. 113. WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141,145,147.

Eponides multicameratus KLEINPELL, 1938, Miocene Stratigraphy of California, p. 320, pl. 19, fig. 2,3,7 (Contains prior synonymy).

Test trochoid, medium in size, in the adult form almost biconvex, umbilicate, both sides rather flattened, periphery broadly rounded, slightly lobulate, edge broadly rounded; chambers distinct, slightly inflated, about 11 to 13 in the last-formed whorl in the adult; sutures distinct, depressed, earlier ones slightly curved, nearly radial; wall smooth, finely perforate; aperture a narrow arched opening at the base of the last-formed septal face midway between the periphery and the umbilicus. Diameter, 0.57 mm.; thickness, 0.45 mm. Common.

The author has observed the holotype of *Eponides multicameratus* Kleinpell and it has a *Gyroidina*-type aperture and an umbilicus on the ventral side. Therefore, this species has been placed in the genus *Gyroidina*.

Hypotype.—USC No. 3597.

Genus VALVULINERIA Cushman, 1926
VALVULINERIA ALICIA Pierce, n. sp.
Pl. 141, fig. 3

Test trochoid, subcircular in outline, biconvex, dorsal side somewhat flattened, ventral side rather strongly convex, especially the last-formed chamber, periphery broadly rounded and slightly lobulate, edge rounded, rather well developed umbo on dorsal side; chambers 8 to 9 in the last-formed whorl, all chambers visible on dorsal side, slightly inflated, more so on the ventral side, uniformly shaped, and increasing in size rather rapidly as added; sutures depressed, slightly oblique, curved dorsally, ventrally slightly curved, nearly radial, narrowly limbate on dorsal side; wall smooth, finely perforate; aperture an arched slit on the ventral margin of the last-formed chamber and extending into the umbilicus with a slight lip and almost completely covered on the ventral side by an umbilical flap. Diameter, 0.57 mm.; thickness, 0.30 mm. Present.

This species differs from *Valvulineria johnsoni* Coryell & Mossman in having a greater number of chambers, thicker in edge view, more broadly rounded periphery, chambers being more uniformly shaped, and not increasing in size as rapidly as the chambers are added.

Holotype.—USC No. 3601.

Genus HANZAWAIA Asano, 1944
HANZAWAIA ILLINGI (Nuttall)
Pl. 142, fig. 1

Truncatulina illingi NUTTALL, 1928, Quart. Jour. Geol. Soc., vol. 84, pt. 1, p. 97–98, pl. 7, fig. 11,17.

Cibicides sp. cf. *C. illingi* (Nuttall) WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141,145.

Cibicides illingi KLEINPELL, 1938, Miocene Stratigraphy of California, p. 354, pl. 19, fig. 10, pl. 20, fig. 18,19,20.

Test trochoid, compressed, dorsal side somewhat flattened, umbilical area on dorsal side covered with irregular outlined supplementary lobes, ventral side somewhat more convex than dorsal side, subcircular in side view, periphery nearly smooth, edge acute; chambers not inflated, about 5 or 6 in the last-formed whorl, rather uniformly shaped except for the initial chamber which is bulbously-shaped in the megalospheric form, increasing in size very gradually as added; sutures strongly curved, raised and limbate on both sides; wall smooth, finely perforate; aperture an arched-like opening extending along the spiral suture for 2 or 3 chambers dorsally, with a slight lip. Diameter, 0.40 mm.; thickness, 0.22 mm. Rare.

The writer has moved this species from *Cibicides* to *Hanzawaia* because the umbilical area on the dorsal side is covered with irregularly outlined supplementary lobes.

The genus *Hanzawaia* Asano, 1944 has time priority over the genus *Cibicidina* Bandy, 1949.

Hypotype.—USC No. 3605.

Family HETEROHELICIDAE Cushman, 1927
Genus BOLIVINA d'Orbigny, 1839
BOLIVINA BENEDICTENSIS Pierce, n. sp.
Pl. 142, fig. 9

Bolivina hughesi RANKIN, 1931, *in* Hoots, U. S. Geol. Surv. Prof. Paper 165-C, p. 113,114. WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 144. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 273.

Test elongate, about 2½ to 3 times as long as broad, round in cross section, slightly compressed, whole test twisted, periphery rounded; chambers biserial, 8 to 12 pairs, the last three pairs making up half the test, increasing in height toward the apertural end; sutures flush to slightly depressed in early ones becoming more depressed in later ones, and meeting the periphery at almost 90 degrees; wall smooth, finely perforate; aperture elongate, narrow slit slightly curving bordered by a raised lip. Length, 0.92 mm.; breadth, 0.35 mm.; thickness, 0.30 mm. Common.

Upon examining the holotype of *Bolivina hughesi* Cushman, 1926, it was found that the sutures were not straight like those figured by Cushman but were very similar to those of *Bolivina sinuata* Galloway and Wissler var. *alisoensis* Cushman and Adams, 1935. In short, the holotype specimen of *Bolivina hughesi* Cushman, 1926, does not agree with the original figure by Cushman. However, *Bolivina hughesi* Cushman, 1926, has been correctly figured and described by Ruth Todd in Cushman's, *A Monograph of the Foraminiferal Subfamily Virgulininae*, p. 117, pl. 14, fig. 7a,b. This new species could be made a subspecies of *Bolivina hughesi* Cushman but would cause more confusion at a later date because other authors would elevate it from a subspecies to a species. Therefore the author has called it *Bolivina benedictensis* Pierce, n. sp.

Holotype.—USC No. 3610.

BOLIVINA GRANTI Rankin
Pl. 143, fig. 1

BOLIVINA sp. RANKIN, 1931, *in* Hoots, U. S. Geol. Surv. Prof. Paper 165-C, p. 113.

Bolivina granti RANKIN, 1934, *in* Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, p. 21, pl. 4, fig. 2,3.

Bolivina goukoffi RANKIN, 1934, *in* Cushman & Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, p. 22, pl. 4, fig. 4,5.

Bolivina granti WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 144. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 272–273.

Bolivina goudkoffi KLEINPELL, 1938, Miocene Stratigraphy of California, p. 272.

Test elongate, about twice as long as broad, somewhat tapering and somewhat rhomboid in cross section, often contracted toward the apertural end, frequently twisted; chambers biserial, 6 to 8 pairs, the last three making up half of the test, slightly inflated, rather high but usually with irregular overlapping, giving a lack of uniformity to the shape and size; sutures slightly depressed, curving, usually irregular in their angle with the periphery, with a small lobe near the median line in the adult stage; wall fine to mediumly perforate, smooth; aperture elongate, elliptical, and slightly curved slit bordered by a narrow lip. Length, 0.65 mm.; breadth, 0.32 mm.; thickness, 0.22 mm. Rare.

Upon examining the holotypes and the paratypes of both *Bolivina granti* Rankin and *Bolivina goudkoffi* Rankin the author found these two specimens to be conspecific and the former has page priority; therefore these two species have been placed in one species, *Bolivina granti* Rankin, in this study.

Hypotype.—USC No. 3618.

BOLIVINA HUGHESI Cushman
Pl. 143, fig. 2

Bolivina hughesi CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 2, no. 29, p. 43, pl. 6, fig. 4a,b. RANKIN, 1931, *in* Hoots, U. S. Geol. Surv. Prof. Paper 165-C, p. 113,114.

Bolivina sinuata Galloway & Wissler var. *alisoensis* CUSHMAN & ADAMS, 1935, *in* Cushman & Adams, Contr. Cushman Lab. Foram. Res., vol. 11, p. 19–20, pl. 3, fig. 5.

Bolivina hughesi WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 144.

Bolivina sinuata alisoensis WOODRING, BRAMLETTE & KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141.

Bolivina sinuata var. *alisoensis* CUSHMAN & TODD, 1937, A Monograph of the Foraminiferal Subfamily Virgulininae, Contr. Cushman Lab. Foram. Res., Special Publ. 9, p. 121, pl. 11,

fig. 22–24. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 282.
Bolivina hughesi KLEINPELL, 1938, Miocene Stratigraphy of California, p. 273.

Test elongate, about 2 to 3 times as long as broad, slightly compressed, round in cross section, sides tapering, somewhat twisted about the longitudinal axis, initial end rounded in the megalospheric forms and bluntly pointed in the microspheric forms; chambers biserial, slightly inflated, about 7 to 10 pairs, the last three pairs making up about half of the test, increasing in size uniformly; sutures depressed, crenulated and tend to develop a lobate character, making an angle of about 80 to 90 degrees with the periphery; wall finely perforated, four longitudinal rows of weak nodular projections on the later portion of the test; aperture elongate slit bordered by a narrow lip on the inner face of the ultimate chamber. Length, 0.88 mm.; breadth, 0.45 mm.; thickness, 0.40 mm. Common to abundant.

The holotype of *Bolivina hughesi* Cushman and the holotype of *Bolivina sinuata* Galloway & Wissler var. *alisoensis* Cushman & Adams were compared by Miss Ruth Todd of the U. S. Geol. Survey and were found to be synonymous. *Bolivina hughesi* Cushman, 1926, has priority over *Bolivina sinuata* Galloway & Wissler var. *alisoensis* Cushman & Adams, 1935.

Hypotype.—USC No. 3619.

BOLIVINA MARGINATA Cushman var. MONICANA Pierce, n. var.
Pl. 143, fig. 3

Test elongate, about 1½ to 2 times as long as broad, very much compressed, elliptical in cross section, edge subacute in the earlier portion to subround in the adult stage, usually with a slight keel; chambers biserial, appressed, increasing in size uniformly, 7 to 11 pairs, the last three making up about half of the test; sutures slightly depressed to raised, limbate, curved, making an angle of about 45 degrees with the periphery; wall finely perforated, smooth; aperture an elongate slit bordered by a narrow lip. Length, 0.78 mm.; breadth, 0.40 mm.; thickness, 0.20 mm. Very abundant.

It differs from the typical form in having greater breadth in the later chambers and the more limbate sutures.

Holotype.—USC No. 3620.

Phylum CHORDATA
Class OSTEICHTHYES
Order ISOSPONDYLI
Family CLUPEIDAE
Genus XYNE Jordan & Gilbert
XYNE GREX Jordan & Gilbert
Pl. 144, fig. 1

Xyne grex JORDAN & GILBERT, 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 25. JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fishes of diatom beds of Lompoc, California, p. 9. JORDAN & GILBERT 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 242. DAVID, 1943, Geol. Soc. of America, no. 43, p. 54,55,89–93,120. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, p. 37, pl. 3, fig. 29.

Scale subround to slightly subquadrate, about 1½ times as long as broad and varying to as broad as long, usually with a slight median basal lobe; apical part is separated from basal part by a complete transverse line; nucleus midway between lateral margins of scale and just above the apical part of the scale; lateral folds or transverse radii 2 to 6, with a few of the lateral folds turning sharply downward near the center of the scale; circuli closely spaced and meeting the lateral margins almost at right angles. Length, 5 mm.; breadth, 5.50 mm. Common to very abundant in upper Mohnian.

The scale of this species differs from the scale of *Ganolytes aratus* (Jordan) and *Ganolytes cameo* Jordan in that the scale of *Xyne grex* Jordan & Gilbert has lateral folds that turn downward rather sharply near the center of the scale, has no tubercles or depressions which characterize the *Ganolytes* scales; scales are much thinner than the *Ganolytes* scales; and the circuli are usually parallel to one another, whereas many of the circuli of the *Ganolytes* sp. converge with other circuli.

Hypotype.—USC No. 3634.

Genus GANOLYTES
GANOLYTES ARATUS (Jordan)
Pl. 144, fig. 2

Thyrison velox JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fishes of diatom beds of Lompoc, California, pl. 9.
Diradias aratus JORDAN, 1924, Southern Calif. Acad. Sci. Bull., vol. 23, p. 42, pl. F.
Diradias fenestralis JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 9, pl. 1.
Xenothrissa aphrasta JORDAN, 1925, Stanford Univ. Publ., Bio. Scil., vol. 5, no. 1, p. 10, pl. 2.

Bellion peronides JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 5, no. 1, p. 16, pl. 7.
Diradias aratus JORDAN, 1927, Stanford Univ. Publ., Biol. Sci., vol. 5, no. 2, p. 39.
Ganolytes aratus DAVID, 1943, Geol. Soc. of Amer., Special Papers no. 43, p. 120–122, fig. 21. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 37–38, fig. 4(?)

Scale subround to almost subquadrate, about 1½ times as broad as long and varying to as long as broad, usually with a slight median basal lobe, edge very thick; apical part is separated from basal part by a complete transverse line; nucleus midway between lateral margins of scale and just above the apical part of the scale; may be with or without lateral folds, with small tubercles or depressions on basal part near lateral folds; circuli closely spaced and often converge with the other circuli, and meet the lateral margins of the scale almost at right angles. Common to abundant. Length, 10 mm.; breadth, 12 mm.

Hypotype.—USC No. 3635.

GANOLYTES cf. G. CAMEO Jordan
Pl. 144, fig. 3

Ganolytes cameo JORDAN, 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 6, pl. 2,4. JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 241, pl. 15.
Diradias fenestralis JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, pl. 9.
Diradias aratus JORDAN, 1924, Southern California Acad. Sci. Bull., vol. 23, p. 24.
Diradias fenestralis JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 9, pl. 1.
Diradias aratus JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 8. JORDAN, 1927, Stanford Univ. Publ., Biol. Sci., vol. 5, no. 2, p. 5.
Ganolytes cameo DAVID, 1943, Geol. Soc. of Amer., Spec. Pap. no. 43, p. 3, pl. 1, fig. 1. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 37–38, pl. 3.

Scale subround to nearly subquadrate, about 1¼ times as broad as long and varying to as long as broad, usually with a slight median basal lobe, edge very thick; apical part of scale is separated from basal part by a complete transverse line; nucleus midway between lateral margins of scale and just above apical part; usually with irregular lateral folds on the basal part and the ends of the lateral folds are often marked by small round depressions or tubercles; circuli closely spaced, often converge with other circuli and meet the lateral margins of the scale almost at right angles. Length, 10 mm.; breadth, 13 mm. Common.

The scale of this species differs from the scale of *Ganolytes aratus* in that the former has stronger lateral folds.

Hypotype.—USC No. 3636.

Family DUSSUMIERIDAE
Genus ETRINGUS
ETRINGUS SCINTILLANS Jordan
Pl. 144, fig. 4

Etringus scintillans JORDAN, 1907, Univ. of Calif. Publ., Geol. Sci., vol. 5, p. 121, fig. 17,20. JORDAN, 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 5, pl. 1,3. JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 241. DAVID, 1943, Geol. Soc. Amer., Spec. Pap., no. 43, p. 6, pl. 1, fig. 2,3. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 36, fig. 4.

Scale elongate to subround to almost subquadrate, about 1½ times as long as broad to about as broad as long, may or may not have a weakly developed median basal lobe, edge of scale thinner than the scale of *Ganolytes* sp.; apical part is not completely separated from basal part by a transverse line, may be with or without apical radii; nucleus near the posterior most paired lateral folds and midway between the lateral margins of the scale; numerous paired lateral folds; circuli closely spaced but usually do not converge and make a 60 to 90 degree angle with the lateral margins of the scale. Length, 9 mm.; breadth, 6 mm. Common to abundant in early upper Mohnian and lower Mohnian stage.

Hypotype.—USC No. 3637.

Family BATHYLAGIDAE
Genus BATHYLAGUS Günther
BATHYLAGUS (QUAESITA) ANGELENSIS
(Jordan & Gilbert)
Pl. 144, fig. 5

Azalois angelensis JORDAN & GILBERT, 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 32, pl. 15.
Lygisma tenax JORDAN & GILBERT, 1919, Stanford Univ. Publ., Fossil fishes of Southern California, p. 33, pl. 7,14. JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fishes of diatom beds of Lompoc, California, p. 12. JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 248, pl. 21.
Azalois angelensis JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 249, pl. 23.
Bathylagus (Quaesita) angelensis DAVID, 1943, Geol. Soc. Amer., Spec. Pap. no. 43, p. 55, pl. 7, fig. 3, pl. 8, fig. 4, pl. 9, fig. 3,4.

Total length of specimen 62 mm., structure of head and body slender, head 1½ times as long as deep, body about 2½ times as long as head; bones of skull very delicate, indistinct in most cases, parasphenoid rod-like, very long, dividing orbit into two halves; quadrate not too distinct but appears to be fan shaped with radiating ridges; mesopterygoid large, forming almost a half circle, mesopterygoid and entopterygoid in place close to parasphenoid; hyoid arch represented by two spindle-shaped ceratohyalia with radiating ridges on ends of spindles; three branchiostegal are present; right and left mandibular forming triangular bones; teeth are not present in this specimen; maxilla and supramaxilla form an elongate, sole-shaped bone, supramaxilla ornamented by half concentric ridges; vomer not present in this specimen; pectoral girdle with cleithrum, supracleithrum and slender rod-like bones strengthen the upper half of the rounded cleithrum, lower end of cleithrum thickened and turns forward; vertebrae 44, longer than deep, loosely connected, vertebrae have a number of longitudinal ridges; dorsal fin with 9–12 spines and with 10–12 rays, origin of dorsal somewhat beyond middle of body, dorsal inserted above 19th vertebra; anal fin with 14–15 rays and behind base of dorsal fin; pectoral fins with 7 rays; pelvic fins with 8 rays. Length, 62 mm. Occurs only in the *Bolivina granti* zone in this locality.

No fish scales of this species were found, only fish skeletons.

Hypotype.—USC No. 3638.

Order INIOMI
Family MYCTOPHIDAE
LAMPANYCTUS BOLINI David
Pl. 144, fig. 6,7

Lampanyctus bolini DAVID, 1943, Geol. Soc. Amer., Spec. Pap. no. 43, p. 64–65, pl. 7, fig. 2, pl. 9, fig. 1,2.

Scale subround to almost round, about as long as broad, weakly developed median basal lobe; 2 to 3 basal radii; nucleus very large and centered; circuli continue across both basal and apical parts of scales enclosing the inner circuli. Length, 1.65 mm.; breadth, 2 mm. Common to abundant in *Bolivina granti* zone. Skeleton was identified by the scales. Length, 75 mm.

Hypotype.—USC No. 3639.

Order PERCOMORPHI
Family CARANGIDAE
DECAPTERUS (LOMPOCHITES) cf. D. HOPKINSI (Jordan)
Pl. 144, fig. 8

Lompochites hopkinsi JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fishes of diatom beds of Lompoc, California, p. 30, pl. 20. JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 276, pl. 4.

Coronadus agilus JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 1, p. 28, pl. 14.

Decapterus (*Lompochites*) *hopkinsi* DAVID, 1943, Geol. Soc. of Amer., Spec. Pap. 43, p. 147–149, fig.

Decapterus (*Lompochites*) cf. *hopkinsi* DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 39, pl. 4, fig. 37.

Scale almost round to round, about as long as broad; nucleus small, round and almost in the center of the scale; circuli almost round, closely spaced and enclosing each inner circuli. May or may not have basal radii which radiate out toward anterior part of scale. Length, 3 mm.; breadth, 3 mm. Common to abundant.

Hypotype.—USC No. 3640.

Family SCIAENIDAE
Genus LOMPOQUIA
LOMPOQUIA CULVERI (Jordan)

Turio culveri JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 23, pl. 10.

Lompoquia culveri DAVID, 1943, Geol. Soc. of Amer., Spec. Pap. 43, p. 135–136, fig. 26b.

Lompoquia cf. *culveri*. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 41, pl. 5, fig. 51,51a.

Scale rectangular to almost square; apical end flatly convex to even, with marginal spines; basal part making up about ¾ to ⅞ of the scale, with 10 basal radii arranged fanwise; nucleus near apex, small and almost circular; circuli closely spaced, very distinct, lateral ones parallel with margins. Present. Length, 4 mm.; breadth, 3.15 mm.

Hypotype.—USC No. 3641.

LOMPOQUIA RETROPES Jordan & Gilbert
Pl. 144, fig. 9

Lompoquia retropes JORDAN & GILBERT, 1919, Stanford Univ., Publ. Fossil fishes of Southern California, p. 44, pl. 24. JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fishes of diatom beds of Lompoc, California, p. 30, pl. 19. JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 281, pl. 47.

Atkinsonella strigilis JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 281, pl. 5,41.
Lompoquia retropes JORDAN, 1924, Southern California Acad. Sci. Bull., vol. 23, p. 47, pl. k. JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 32, DAVID, 1943, Geol. Soc. Amer., Spec. Pap. no. 43, p. 133, pl. 16, fig. 2,26a (Contains prior synonymy.)

Scale rectangular to almost square, about $1\frac{1}{3}$ times as broad as long to longer than broad; apical end flatly convex with marginal spines; basal end making up about $\frac{3}{4}$ to $\frac{7}{8}$ of the scale, anterior end with almost square corners, with 6 to 8 strongly marked basal radii, arranged fanwise; nucleus near apex, small and almost circular; circuli closely spaced, very distinct, lateral ones parallel with margins. Common to abundant. Length, 4.5 mm.; breadth, 6.5 mm.

In this study the scales of this species have been distinguished from the scales of *Lompoquia culveri* (Jordan) in that the former usually has 6 to 8 basal radii; whereas the latter has 10 basal radii.

Hypotype.—USC No. 3642.

Family SCOMBRIDAE
Genus PNEUMATOPHORUS Jordan & Gilbert
PNEUMATOPHORUS cf. *P. grex* (Mitchell)
Pl. 144, fig. 12

Turio wilburi JORDAN & GILBERT, 1920, Stanford Univ. Publ., Fossil fish of diatom beds of Lompoc, California, p. 15, pl. 6,8.
Auxides dasson JORDAN, 1921, Stanford Univ. Publ., Biol. Sci., vol. 1, no. 4, p. 269, pl. 3,36.
Turio wilburi JORDAN, 1925, Stanford Univ. Publ., Biol. Sci., vol. 4, no. 1, p. 23.
Pneumatophorus cf. *grex* DAVID, 1943, Geol. Soc. of Amer., Spec. Pap. 43, p. 151. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 39, pl. 4, fig. 34.

Scale elongate, about $1\frac{1}{2}$ times as broad as long; apical part flatly convex; basal part flatly convex; nucleus centered and adjacent basal and apical circuli almost parallel, circuli of basal region more widely spaced than the apical circuli. Present to common. Length, 5.70 mm.; breadth, 4 mm.

The scale of this species differs from the scale of *Sarda* cf. *S. stockii* David in that the former has adjacent basal and apical circuli which are almost parallel whereas the circuli of the latter are irregularly angled and curved.

Hypotype.—USC No. 3643.

Family THUNNIDAE
Genus SARDA Cuvier
SARDA cf. S. STOCKII David
Pl. 144, fig. 10

Sarda stockii DAVID, 1943, Geol. Soc. Amer., Spec. Pap. no. 43, p. 31–33, 155, pl. 4.
Sarda cf. *stockii* DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 39,41, pl. 4, fig. 35,36.

Scale elongate to subround, about $1\frac{1}{2}$ times as broad as long varying to about as long as broad; apical part flatly convex; basal part flatly convex; nucleus centered, ovoid to irregularly angled; circuli of basal region almost circular concentric to irregularly angled, usually more widely spaced than the apical circuli. Present to common. Length, 1.60 mm.; breadth, 2 mm.

Hypotype.—USC No. 3644.

Family POTATOMIDAE
Genus PSEUDOSERIOLA David, 1943
PSEUDOSERIOLA sp. David
Pl. 144, fig. 14

Pseudoseriola sp. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 41, pl. 5, no. 44.

Scale quadrangular, about $1\frac{1}{4}$ times as broad as long; apical part flatly convex; basal part straight and folded concentrically; nucleus centered, subquadrate and small; circuli closely spaced, central circular almost symmetrically rectangular, outer circular almost parallel with margins. Present. Length, 3 mm.; breadth, 4 mm.

Hypotype.—USC No. 3645.

Family ATHERINIDAE
ATHERINIDAE no. 1
Pl. 144, fig. 13

Scale almost quadrate, about $1\frac{1}{2}$ times as broad as long; apical end flatly convex, usually with small marginal spines; basal end almost straight, no basal radii on this scale, dorsal-basal and ventral-basal margins almost forming a right angle; nucleus not visible in this scale; circuli transverse and very closely spaced in the middle basal part of the scale forming an acute latero-basal angle with the outer marginal circuli which run almost parallel with the dorsal and ventral margins of the scale, the outer marginal circuli are more widely spaced than the V-shaped, transverse inner basal

circuli with the former continuing down to the ventral-apical and dorsal-apical corners but not across the apical end. Present. Length, 1.5 mm.; breadth, 2.5 mm.

This scale differs from Atherinidae no. 2 and Atherinidae no. 4 in that the circuli do not continue across the apical end and it is characterized by its greater breadth than length.

Hypotype.—USC No. 3649.

The family name Atherinidae has been used in this study because Atherinidae no. 1, 2, and 4 scales come from an undescribed genus and species or genera and species. It is possible that these three scales come from the same species and that these minor differences are produced because the scales come from different parts of the fish's body.

ATHERINIDAE no. 2
Pl. 144, fig. 16

Zanteclites sp. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 39, pl. 4, no. 33, pl. 6, no. 2.

Scale almost quadrangular, about $1\frac{1}{4}$ times as long as broad; apical end convex; basal end straight, with basal-dorsal and basal-ventral margins almost forming right angles, basal radii may or may not be present, but is present in this scale; nucleus small and circular, almost centered; circuli transverse and very closely spaced in the middle basal part of the scale forming an acute laterobasal angle with the outer marginal circuli which run almost parallel with the dorsal and ventral margins of the scale, the outer marginal circuli are more widely spaced than the V-shaped transverse inner basal circuli. Common. Length, 4 mm.; breadth, 3.50 mm.

Hypotype.—USC No. 3647.

ATHERINIDAE no. 4
Pl. 144, fig. 17

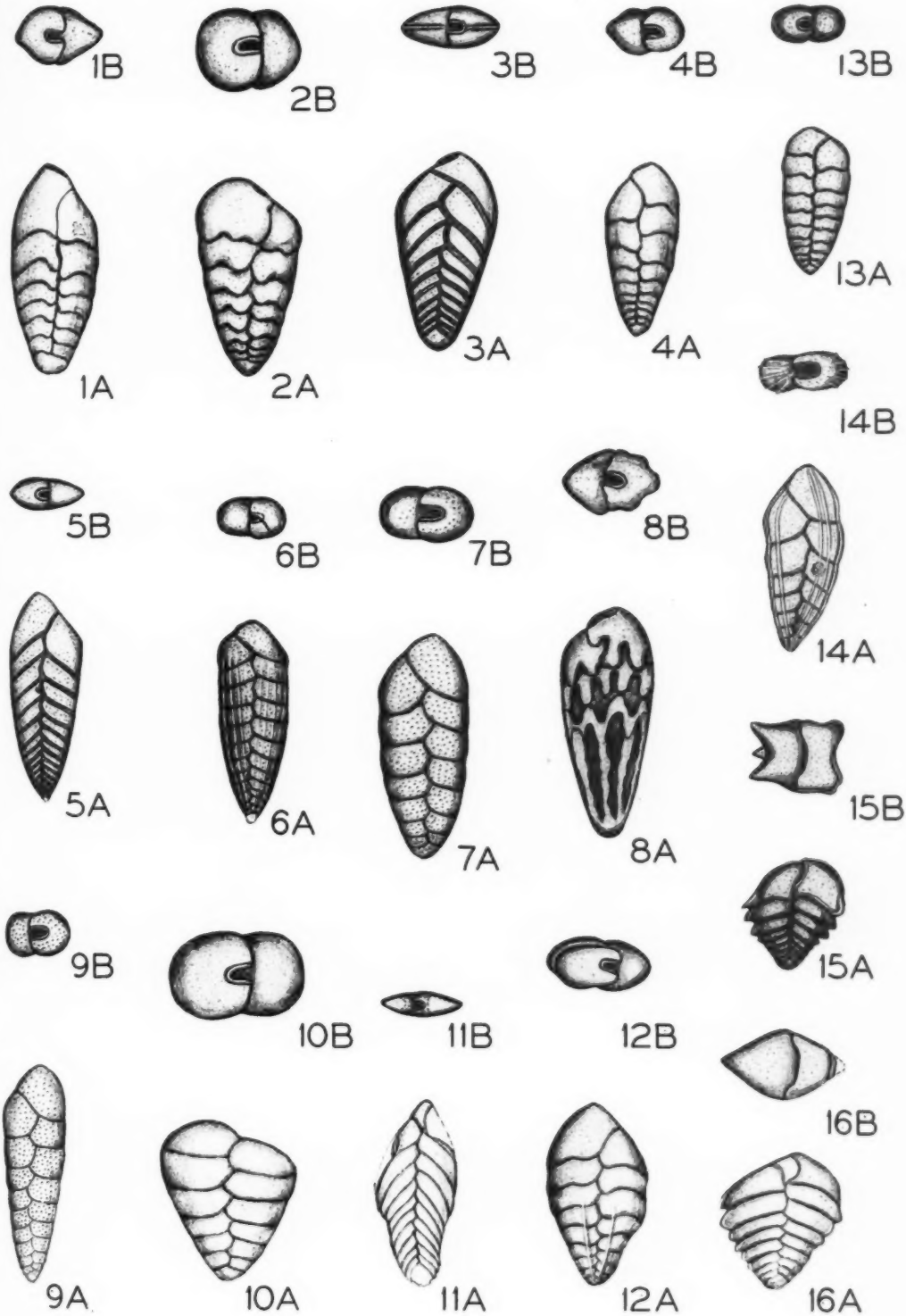
Atherinidae cf. *A.* no. 49a David, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 41, pl. 5, no. 49.

Scale elongate, about as broad as long, apical end convex, basal end almost straight, no basal radii present in this scale, basal-dorsal and basal-ventral marginal corners forming almost a 90 degree angle; nucleus almost circular to somewhat flattened; circuli transverse and very closely spaced in the middle basal part of the scale forming an acute laterobasal angle with the outer marginal circuli which run almost parallel with the dorsal and ventral margins of the

---

EXPLANATION OF PLATE 143

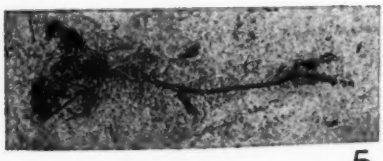
FIG. *1*—*Bolivina granti* Rankin, ×46; a, side view; b, apertural view; hypotype, USC No. 3618.
2—*Bolivina hughesi* Cushman, ×32; a, side view; b, apertural view; hypotype, USC No. 3619.
3—*Bolivina marginata* Cushman var. *monicana* Pierce, n. var., ×36; a, side view; b, apertural view; holotype, USC No. 3620.
4—*Bolivina perrini* Kleinpell, ×25; a, side view; b, apertural view; hypotype, USC No. 3621.
5—*Bolivina pseudospissa* Kleinpell, ×32; a, side view; b, apertural view; hypotype, USC No. 3623.
6—*Bolivina salinasensis* Kleinpell, ×48; a, side view; b, apertural view; hypotype, USC No. 3624.
7—*Bolivina seminuda* Cushman var. *humilis* Cushman and McCulloch, ×45; a, side view; b, apertural view; hypotype, USC No. 3625.
8—*Bolivina sinuata* Galloway and Wissler, ×29; a, side view; b, apertural view; hypotype, USC No. 3626.
9—*Bolivina tumida* Cushman, ×52; a, side view; b, apertural view; hypotype, USC No. 3628.
10—*Bolivina tumida* Cushman var. *cuneata* Kleinpell, ×83; a, side view, b, apertural view; hypotype, USC No. 3629.
11—*Bolivina pisciformis* Galloway and Morrey, ×31; a, side view; b, apertural view; hypotype, USC No. 3522.
12—*Bolivina woodringi* Kleinpell, ×29; a, side view; b, apertural view; hypotype, USC No. 3631.
13—*Bolivina vaughani* Natland, ×45; a, side view; b, apertural view; hypotype, USC No. 3630.
14—*Bolivina tongi* Cushman, ×46; a, side view; b, apertural view; hypotype, USC No. 3627.
15—*Suggrunda californica* Kleinpell, ×38; a, side view; b, apertural view; hypotype, USC No. 3632.
16—*Suggrunda kleinpelli* Bramlette, ×46; a, side view; b, apertural view; hypotype, USC No. 3633.


1B
2B
3B
4B
13B
1A
2A
3A
4A
13A
14B
5B
6B
7B
8B
14A
5A
6A
7A
8A
15B
9B
10B
11B
12B
15A
16B
9A
10A
11A
12A
16A

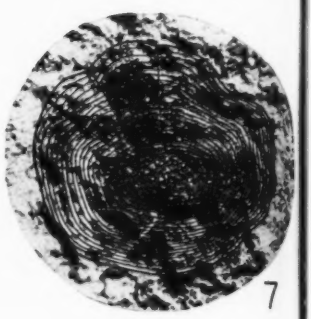
1

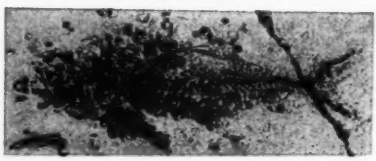
2

3

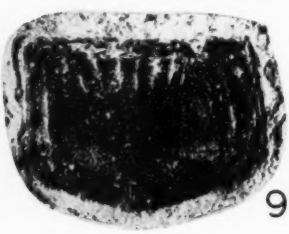

5

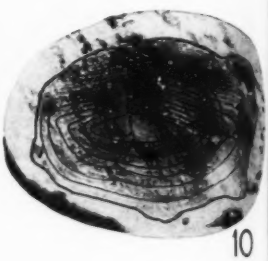
4


7

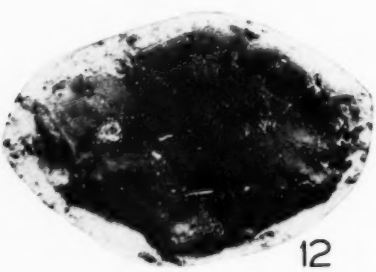

6

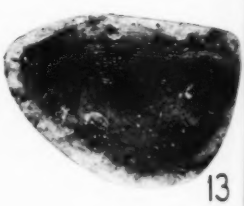
8


9

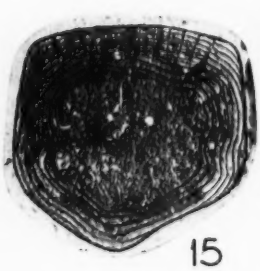

10

11

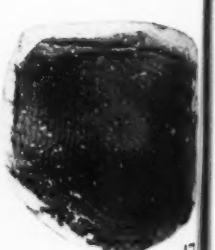

12


13

14


15

16


17

scale, the outer marginal circuli are more widely spaced than the V-shaped transverse inner basal circuli and the former becomes very closely spaced as it crosses the apical part of the scale. Present. Length, 5 mm.; breadth, 5 mm.

Atherinidae no. 4 differs from Atherinidae no. 2 in that the former is more quadrate in outline, somewhat inverted V-shaped apical end and the outer circuli become more closely spaced as they cross the apical end.

Hypotype.—USC No. 3648.

Order SCLEROPAREI
Family SCORPAENIDAE
Genus SEBASTODES Gill
SEBASTODES aff. S. ELONGATUS Ayres
Pl. 144, fig. 15

Sebastodes sp. DAVID, 1944, Carnegie Inst. of Washington Publ. 551, pt. 3, p. 40, pl. 4, no. 41.
Sebastodes aff. *elongatus* DAVID, 1945, Richfield fish types no. 97 (manuscript).

Scale subquadrate, about as long as broad, apical part flatly convex and usually has marginal spines, basal end almost straight and with numerous distinct, short basal radii; nucleus and center circuli usually not visible but covered by a roughened surface; circuli near margins almost straight and nearly parallel with margins. Present to common. Length, 6 mm.; breadth, 6 mm.

Hypotype.—USC No. 3646.

BIBLIOGRAPHY

ANDERSEN, H. V., 1952, A new genus of the rotalid Foraminifera: Wash. Acad. Sci., Jour., Vol. 42, no. 5, p. 143–151.

BANDY, O. L., 1953, Ecology and paleoecology of some California Foraminifera; Part I: The frequency distribution of Recent Foraminifera off California: Jour. Paleont., vol. 27, p. 161–203, pl. 21–25.

BARBAT, W. F., & JOHNSON, F. L., 1934, Stratigraphy and Foraminifera from the Ridge Reef Shale, Upper Miocene, California: Jour. Paleont., vol. 8, no. 1, p. 3–17.

BRAMLETTE, M. N., 1946, Monterey Formation of California and origin of its siliceous rocks: U. S. Geol. Surv., Prof. Pap. 212, 57 p.

COCKERELL, T. D. A., 1919, Some American Cretaceous fish scales with notes on the classification and distribution of Cretaceous fishes: U. S. Geol. Surv., Prof. Pap. 120, p. 165–188.

CUSHMAN J. A., 1925, Some Textulariidae from the Miocene of California: Cushman Lab. Foram. Res. Contr., vol. 1, pt. 2, p. 29–35.

——, 1926, Foraminifera from the typical Montery of California: Cushman Lab. Foram. Res. Contr., vol. 2, pt. 3, p. 53–66.

——, 1927, Recent Foraminifera from the West Coast of America: Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, no. 10, pp. 119–188.

——, & ADAMS, B. C., 1935, New Late Tertiary Bolivinas from California: Cushman Lab. Foram. Res. Contr., vol. 11, pt. 1, p. 16–20.

——, & ELLISOR, A. C., 1945, The foraminiferal fauna of the Anahuac Formation: Jour. Paleont., vol. 19, p. 545–572.

——, & KLEINPELL, R. M., 1934, New and unrecorded Foraminifera from California Miocene: Cushman Lab. Foram. Res. Contr., vol. 10, pt. 1, p. 1–23.

——, & LAIMING, B., 1931, Miocene Foraminifera from Los Sauces Creek, Ventura County, California: Jour. Paleont., vol. 5, no, 2, p. 79–120.

——, & MCCULLOCH, I., 1942, Some Virgulininae in the collections of the Allan Hancock Foundation: Allan Hancock Pacific Exped., vol. 6, no. 4, p. 179–230.

——, & PARKER, F. P., 1931, Miocene Foraminifera from the Temblor of the east side of San Joaquin Valley, California: Cushman Lab. Foram. Res. Contr., vol. 7, pt. 1, p. 1–15.

EXPLANATION OF PLATE 144

FIG. *1*—*Xyne grex* Jordan & Gilbert, ×5.5; hypotype, USC No. 3634.
2—*Ganolytes aratus* (Jordan), ×2.5; hypotype, USC No. 3635.
3—*Ganolytes* cf. *G. cameo* Jordan, ×3.4; hypotype, USC No. 3636.
4—*Etringus scintillans* Jordan, ×1.5; hypotype, USC No. 3637.
5—*Bathylagus* (*Quaesita*) *angelensis* (Jordan & Gilbert) ×$\frac{3}{4}$; hyoptype, USC No. 3638.
6,7—*Lampanyctus bolini* David, *6*, ×$\frac{1}{2}$; *7*, ×18; hypotype, USC No. 3639.
8—*Decapterus* (*Lompochites*) cf. *D. hopkinsi* (Jordan), ×10; hypotype, USC No. 3640.
9—*Lompoquia retropes* Jordan & Gilbert, ×7.5; hypotype, USC No. 3642.
10—*Sarda* cf. *S. stockii* David, ×18; hypotype, USC No. 3644.
11—*Lompoquia culveri* Jordan, ×6.2; hypotype, USC No. 3641.
12—*Pneumatophorus* cf. *P. grex* (Mitchell), ×7.7; hypotype, USC No. 3643.
13—*Atherinidae* no. 1 David, ×12.4; hypotype, USC No. 3649.
14—*Pseudoseriola* sp. David, ×7.5; hypotype, USC No. 3645.
15—*Sebastodes* aff. *S. elongatus* Ayres, ×4.7; hypotype, USC No. 3646.
16—*Atherinidae* no. 2 David, ×6.9; hypotype, USC No. 3647.
17—*Atherinidae* no. 4 David, ×5.7; hypotype, USC No. 3648.

CUSHMAN, J. A., & TODD, R., A monograph of the foraminiferal subfamily Virgulininae: Cushman Lab. Res. Contr., Spec. Publ. no. 9, p. 1–228.

DAVID, L. R., 1943, Miocene fishes of Southern California: Geol. Soc. Amer., Spec. Pap. no. 43, p. 1–193.

——, 1944, Use of fossil fish scales in micropaleontology: Carnegie Inst. Wash., Publ. 551, pt. 3, p. 25–43.

ELLIS, B. F., & MESSINA, A. R., 1940, Catalogue of Foraminifera: Amer. Mus. Nat. Hist., Spec. Publ., New York.

GALLOWAY, J. J., & WISSLER, S. G., 1927, Pleistocene Foraminifera from the Lomita Quarry, Palos Verdes Hills, California: Jour. Paleont., vol. 1, p. 35–83.

HOOTS, H. W., 1931, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U. S. Geol. Surv., Prof. Pap. 165-C, p. 1–134.

KLEINPELL, R. M., 1938, Miocene stratigraphy of Califonria: Publ. Amer. Assoc. Petrol. Geol., p. 1–450.

LOWMAN, S. W., 1949, Sedimentary facies in the Gulf Coast: Amer. Assoc. Petrol. Geol., Bull., vol. 33, p. 1939–1997.

MARTIN, LEWIS, 1952, Some Pliocene Foraminifera from a portion of the Los Angeles Basin, California: Cushman Lab. Foram. Res. Contr., vol. 111, pt. 3,4, p. 107–141.

NATLAND, M. L., 1933, Temperature and depth distribution of some Recent and fossil Foraminifera in the Southern California Region: Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 3, p. 225–230.

——, 1938, New species of Foraminifera from off the West Coast of North America and from the later Tertiary of the Los Angeles Basin, California: Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 4, no. 5, p. 137–163.

——, 1940, New genus of Foraminifera from the later Tertiary of California: Jour. Paleont., vol. 14, p. 568–571.

STEWART, R. E., & K. C., 1930, Post-Miocene Foraminifera from the Ventura Quadrangle, Ventura County, California: Jour. Paleont., vol. 4, p. 60–72.

WOODRING, W. P., BRAMLETTE, M. N. & KLEINPELL, R. M., 1936, Geology and paleontology of Palos Verdes Hills, California: U. S. Geol. Surv., Prof. Pap. 207, p. 1–145.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1315–1323, 4 TEXT-FIG., NOVEMBER 1956

FERN GLEN (MISSISSIPPIAN) OSTRACODA

DOROTHY JUNG ECHOLS AND JOHN J. GOUTY
Washington University, St. Louis; and Shell Oil Co., New Orleans

ABSTRACT—Results of a systematic study of the Fern Glen ostracode fauna are summarized. This study was concurrent with Benson's published description of these fossils from the type section. The larger collections disclose considerably more variety then previously reported.

STUDIES on the ostracode fauna from the Fern Glen type locality were carried on in the Washington University Micropaleontologic Laboratory at the same time they were being studied by Richard H. Benson (1955, p. 1030–1039) in Illinois. Fortunately, this fact was made known to the writers in April, 1954. It was decided then, after Dr. Benson kindly offered to submit a copy of his manuscript to us, that we would have an opportunity to supplement his paper. This study is published with the permission of the Shell Oil Company.

The conclusions reached by Benson on his faunal studies are substantiated. In the current work, however, not only was the type section at Fern Glen, Missouri, studied; but samples from five other Fern Glen localities were collected and examined for ostracodes (Text-fig. 1).

LOCALITY *1:* Type section, 500 yards west of the railroad station on the north bluffs of the Meramec river at Fern Glen, Missouri, sec. 14, T 44 N, R 4 E. (Text-fig. 2 shows sketch of outcrop.)

DESCRIPTION

9. Gray crystalline limestone with interbedded chert, very fossiliferous. Burlington limestone. 5′ 0″

Zone 4

8. Gray crystalline limestone with interbedded chert, very fossiiiferous, abundant interbedded lenses of green to gray-green highly calcareous shale. These beds are apparently transitional between the Fern Glen proper and the overlying Burlington-Keokuk. No definite break was noted in the microfauna so the bed is included in the Fern Glen. 1′ 2″
7. Shale, green, calcareous, fossiliferous; chert nodules at base. 1′ 2″

Zone 3

6. Shale, calcareous, red, massive, fossiliferous, mottled green in part. 3′ 0″
5. Limestone, red, massive, weathers brown; some chert. 0′ 6″

Zone 2

4. Shale, red, calcareous, more or less massive, very fossiliferous. 5′ 3″
3. Limestone, red, thin-bedded, numerous shale partings, occasional chert nodules. 2′ 3″
2. Shale, calcareous, red, extremely fossiliferous. 3′ 6″

Zone 1

1. Limestone, red, massive, fossiliferous, numerous shale partings, chert nodules common, persistent shale seam about 5 inches thick runs length of section, 18 inches below the top. 9′ 0″

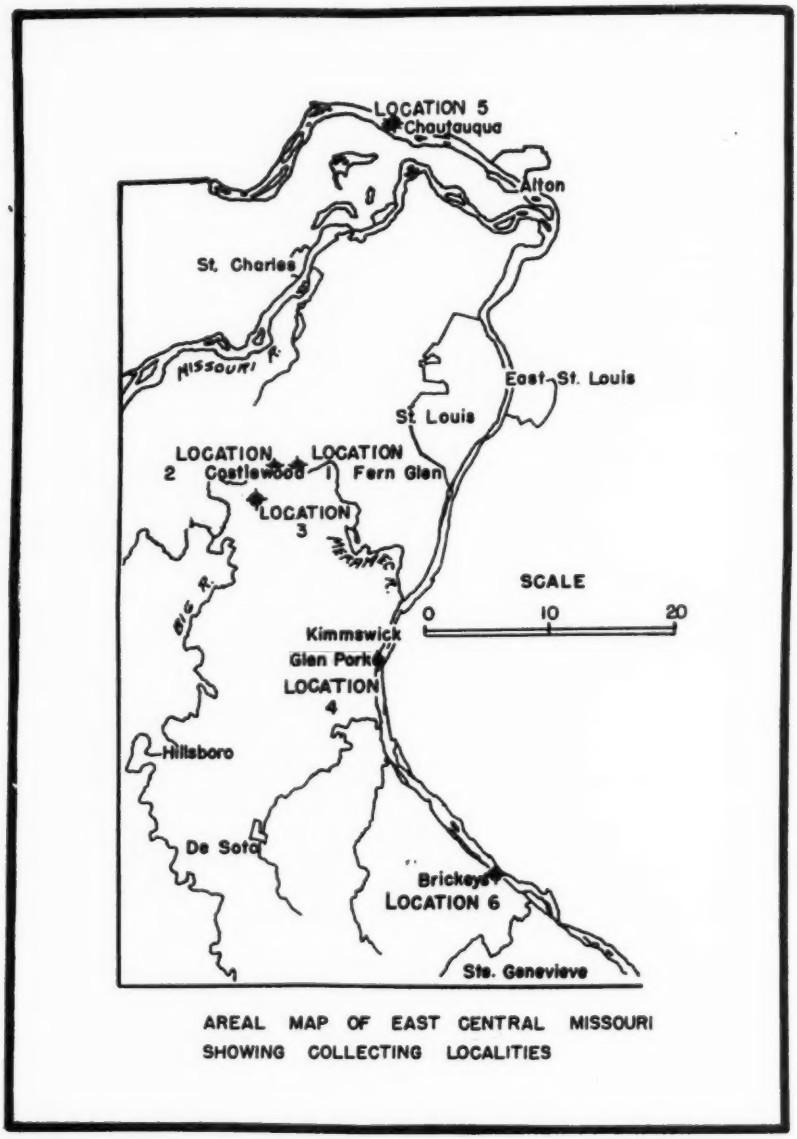
LOCALITY *2:* North Bluff at the Meramec River just east of the railroad station at Castlewood, Missouri, sec. 15, T 44 N, R 4 E.

DESCRIPTION

Burlington: Massive, brown crinoidal limestone; moderately thin-bedded, alternating dense, gray limestone and chert bands. 30′ 0″

Fern Glen Formation

12. Greenish gray, argillaceous limestone, scattered chert nodules, and a band of "silicified stylolite." Transitional bed considered as part of the Fern Glen. 2′ 0″
11. Greenish gray, argillaceous limestone. *Ostracodes.* 1′ 3″
10. Red, argillaceous limestone. *Ostracodes.* 3′ 6″
9. Greenish gray, massive, argillaceous limestone grading to red above. 1′ 0″
8. Massive, dense, gray limestone. 1′ 0″
7. Massive, buff, dense, argillaceous limestone with siliceous nodules and stylolite seams. 8′ 0″
6. Massive, buff, dense limestone with stylolite seams and siliceous nodules. 3′ 0″



AREAL MAP OF EAST CENTRAL MISSOURI SHOWING COLLECTING LOCALITIES

TEXT-FIG. *1*—Locality map.

Bushberg Sandstone

5. Massive, buff, fine-grained sandstone. 8′ 0″

Grassy Creek Shale

4. Conglomerate with phosphatic pebbles. 0′ to 3′ 8″
3. Black fissile shale. 0′ to 3′

Maquoketa Shale

2. Conglomerate with phosphatic pebbles (probably upper Maquoketa). 0′ 8″
1. Maquoketa Shale. 15′ 0″

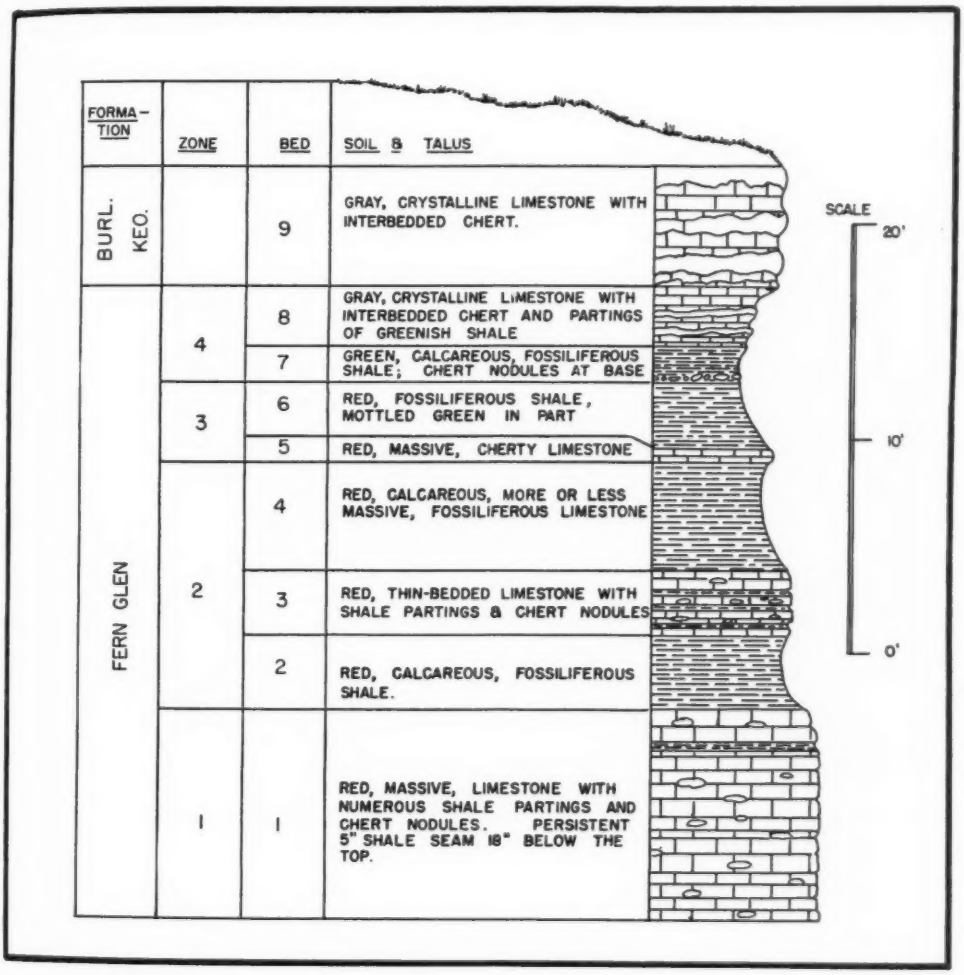
Kimmswick Limestone

Base not exposed.

LOCALITY *3:* Exposure in roadcut on north side of U.S. Highway 66, sec. 34, T 44 N, R 4 E. (This locality was chosen because of the great difference in lithology between it and the type section at Fern Glen.)

	DESCRIPTION	
11.	Limestone, gray fossiliferous, interbedded with chert. Shale seams at base, upper part typical Burlington-Keokuk.	4′ 0″
10.	Buff shale, one persistent limestone bed, some bedded chert.	3′ 0″
9.	Shale, buff with interbedded nodular chert arranged more or less in layers.	1′ 8″
8.	Shale, buff, sandy, numerous fossil imprints, small bands of nodular chert and calcite.	4′ 8″
7.	Columnar, stylolitic, persistent bed of chert.	1′ 0″
6.	Shale, dark blue-gray, highly fossiliferous, sandy. *Ostracodes.*	0′ 1¼″
5.	Shale, silty, olive to blue-gray, calcareous, a few quartz nodules.	3′ 0″
4.	Limestone, soft, sandy, massive, bluish to tan.	1′ 2″
3.	Shale, bluish-gray to brown-gray, sandy, calcareous.	1′ 8″
2.	Limestone, bluish-gray, massive to medium bedded, stylolitic, thin shale partings on bedding planes. Bushberg.	3′ 10″ Bottom not measured

LOCALITY *4:* Fresh railroad cut in river bluff on west bank of the Mississippi River, at Glen Park, Missouri, sec. 5, T 41 N, R 5 E. (Here the formation closely resembles the type section.)



TEXT-FIG. *2*—Sketch of typical Fern Glen exposure.

DESCRIPTION

Fern Glen Formation

8. Limestone, white, crystalline, fossiliferous with interbedded chert and bluish shale. 3′ 0″
7. Shaly lime and limy shale, green-gray. *Ostracodes.* 5′ 0″
6. Shaly lime and limy shale, fossiliferous, thin bedded, red. *Ostracodes.* 5′ 9″
5. Limestone, white, crystalline, fossiliferous, weathers buff. 8′ 0″

Bushberg Sanstone

4. Sandstone, white, weathers buff. 6′ 4″

Glen Park Limestone

3. Limestone, buff colored. 2′ 0″

Maquoketa Shale

2. Shale, gray, thin-bedded, black in bands. 1′ 6″

Kimmswick Limestone

1. Limestone, massive, gray, coarsely crystalline, fossiliferous, chert in part. 20′ 8″

LOCALITY *5:* About 500 feet south of the railroad station at Chautauqua, sec. 18, T 6 N, R 11 W, Jersey County, Illinois, in the north bluff of the Mississippi River. (This is the northernmost outcrop studied.)

DESCRIPTION

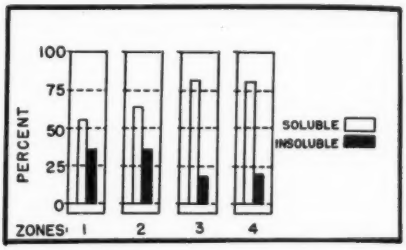
6. Chert, and shaly, buff limestone, numerous shale partings, some chert nodules. 1′ 0″
5. Greenish, very argillaceous limestone, some very thin shaly partings. 1′ 0″
4. Red and green mottled, very argillaceous limestone and limy shale, occasional red and green chert nodules. 1′ 9″
3. Greenish, very limy shale or very shaly limestone, red and green chert at base. 2′ 0″
2. Covered, probably continuation of above bed. 1′ 0″
1. Limestone, massive to thin-bedded, red, green and white chert nodules common, a few shale partings, particularly at the top. 15′ 0″

NO OSTRACODES WERE RECOVERED AT THIS LOCATION.

LOCALITY *6:* About 1000 yards southwest of the railroad station at Brickey's, on Brickey's road, sec. 24, T 39 N, R 7 E. (Outcrop here is slumped and no section could be measured. This is the southernmost locality sampled for this study.)

The type section was studied in detail; it was arbitrarily divided into four zones on lithologic breaks. Each zone was then treated as a unit for the faunal and sedimentary studies.

Sedimentary samples from the type section were collected by channelling from top to bottom of the individual zones. Standard techniques for insoluble residues and mechanical analyses were employed for each of the zones and plotted on histograms. Text-figure 3 is a composite of the soluble and insoluble portions of the four zones.



TEXT-FIG. *3*—Histograms prepared to show relative percentages of solubility within the Fern Glen formation.

The paleontologic samples were washed with the standard procedure and 1000 gram samples from each zone were picked for ostracodes. All of the ostracodes were picked and counted after generic sorting. Seventeen genera and thirty species, including ten new species and one new genus were found.

In addition to the ostracodes some attention was paid to the related fauna. Mehl & Thomas (1947, p. 7) mention the very irregular occurrence of conodonts. The present investigation bears out this observation. Conodonts were found to be rare in all samples except those from Zone 4.

Microcrinoids are well preserved throughout the section. They are abundant in Zones 1 through 3 and not uncommon in Zone 4. The microcrinoids of this formation and other formations of the lower Mississippian have been studied by Peck (1936). Most of the forms found in this study were identified as *Passalocrinus* and *Callimorphocrinus* with the species *Passalocrinus triangularis* Peck being by far the most common.

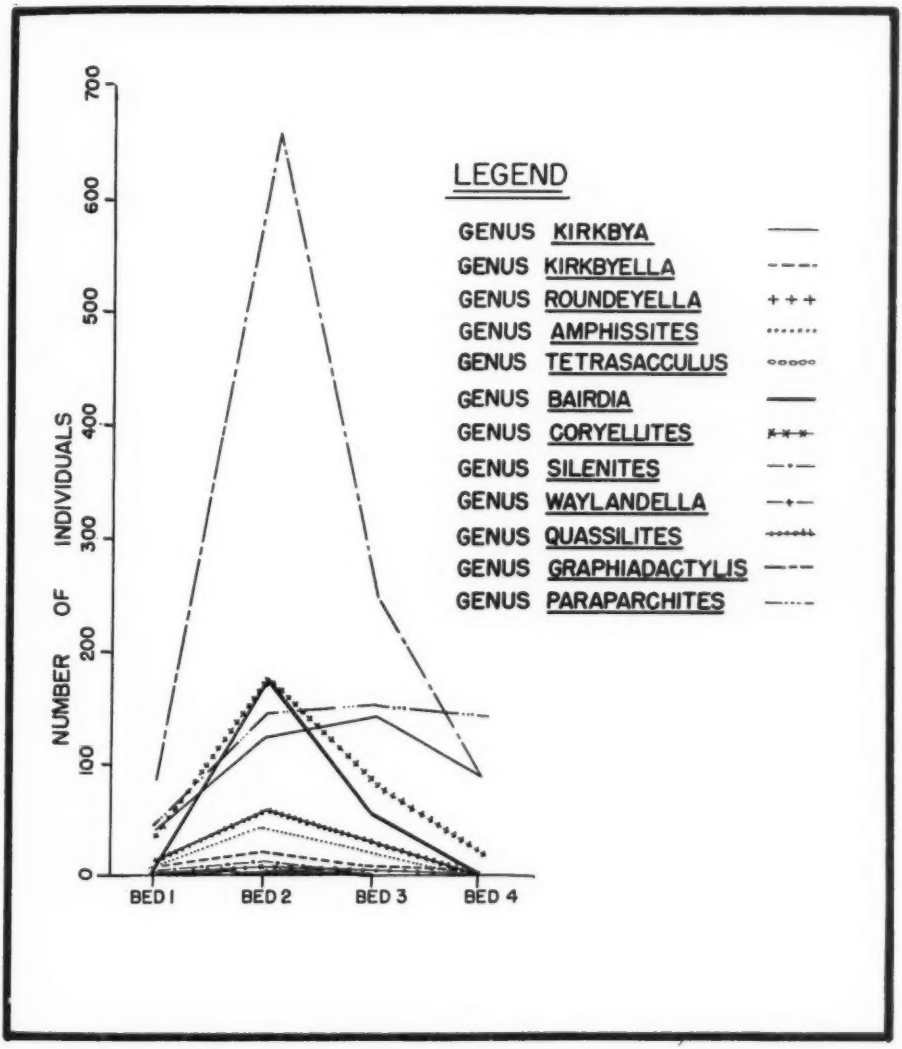
Although usually broken, holothuroid fragments are numerous and relatively constant in numbers. A few excellent specimens

were collected, chiefly from Zones 2 and 3.

Very rare, poorly preserved foraminifera were found throughout the section. Those specimens identified were tentatively assigned to the genera *Endothyra*, *Endothyranella* and *Ammodiscus*.

Tubes of *Spirobis* and other worms are present, they are rare in Zones 2 and 3. Sponge spicules, particularly a very characteristic three-rayed form, are abundant in all zones.

The distribution of ostracodes by count (Text-fig. 4) shows that with the exception of *Paraparchites* and *Kirbya*, all genera reach their culmination as far as numbers of individuals are concerned in Zone 2. Rare forms, such as *Tetrasacculus*, *Waylandella*, and *Healdia* undoubtedly occur throughout the section; but in this systematic study they were found only in the zones noted. (See chart on actual count of specimens.) After this chart was compiled, the junior



TEXT-FIG. 4—Number of individuals of the more common Fern Glen ostracode genera with a 1000 gm. sample.

author collected four random samples in a three foot circle on the face of the outcrop at the type locality. The first sample examined contained very abundant *Graphiadactillis cornutis* and a few very tiny *Kirkbyellas*. The second sample had an average fauna; with the exception of *Kirkbya*, these were all small. The third sample contained a new genus, the only sample in which this genus has been found so far. The fourth sample had abundant, broken specimens of *Amphissites*, common *Tetrassacculus*, and very common *Healdia* sp.

The abundance and quality of preservation of the microfossils varies widely in various parts of the formation. The most abundant fossils occur in Zone 2 while the best preserved are in Zone 3. The ostracodes parallel the rest of the fauna in both instances. In Zone 1 the ostracodes are mashed, and it is difficult to obtain whole specimens. It is, therefore, possible that the overall number of forms in Zone 1 is a bit higher than the count. The specimens in Zone 4 are not broken but are recrystalized to a great degree.

The present position of the Fern Glen is generally accepted as lower Osage. It is separated from the underlying Kinderhook by an unconformity which varies in size throughout the area. The Fern Glen is overlain in all but a few places by the Burlington-Keokuk formation of Osagian age. The Fern Glen has been correlated with the Ridgetop formation of Tennessee.

The fauna of the Fern Glen contains many species of the underlying Kinderhook. Eleven species described by Morey (1936) from the underlying Chouteau and Bushberg (1935) also appear in the Fern Glen. The Fern Glen microfauna, however, more closely resembles later Mississippian assemblages than it does that of the Kinderhook. The more characteristic Devonian forms are replaced by more nearly typical later Mississippian genera. Perhaps the most marked difference between this formation and the underlying Kinderhook is the abundance of representatives of the family Kirkbyidae, the genus *Kirkbya* in particular. The appearance of the genus *Kirkbya* and the increase in number of individuals and species of the entire family of Kirkbyidae may represent the lower boundary of the Osage in eastern Missouri.

On the basis of the sedimentary studies, the type section can be divided into two zones with the top of Zone 2 as the boundary between them. Both the size distribution and the acid soluble content of Zones 1 and 2 are closely related, as are Zones 3 and 4. In general, there is a regular decrease in the fine insoluble from Zone 1 through 4, at the type section.

The ostracode fauna shows some indication of reaching a climax in numbers of individuals just below this sedimentary contact, but the variations in numbers of individuals over even small distances may lead one to believe that this correlation is not reliable.

INDIVIDUALS OF EACH OSTRACODE GENUS FOUND IN 1000 GRAM SAMPLES FROM ZONES OF THE TYPE FERN GLEN

Genus	Zones of the Fern Glen Type Section			
	1	2	3	4
Kirkbya	40	122	138	88
Kirkbyella	5	18	6	2
Roundyella	34	177	85	24
Amphissites	10	45	27	8
Tetrassaculus	2	1	1	
Bairdia	4	175	58	7
Coryellites	2	5	4	1
Silenites	2	6	1	
Waylandella		1	1	
Quassilites	13	59	30	3
Graphiadactyllis	85	600	204	91
Paraparchites	45	145	153	147
Healdia		2		
Bythocypris?		1		
Microchoelenella?		1		
Hypotetragona		1		

A check list of the ostracodes described from the Bushberg, Chouteau, Fern Glen and Ridgetop formations is included for comparison.

The conclusions reached by these faunal and sedimentary studies are not sufficiently complete to reconstruct the environment of deposition of the Fern Glen, in the sampled areas. Nevertheless, the erratic distribution of the microfauna and the variation in numbers over small distances, both horizontally and vertically, make it feasible to assume

TABLE *1*

	Bushberg	Chouteau	Fern Glen	Ridgetop
BUSHBERG, MOREY, *1935*				
Paraparchites nicklesi (Ulrich), 1891	×	×	×	
P. disjunctus Morey, 1935	×			
Plagionephrodes unidosus Morey, 1935	×			
P. marginatus Morey, 1935	×			
Amphissites peculiaris Morey, 1935	×			
A. genetivus Morey, 1935	×			
Kirkbyella scapha Morey, 1935	×			
Graphiadactyllis tumidus Morey, 1935	×			
G. subquadratus Morey, 1935	×			
G. walteri Morey, 1935	×			
G. spinosus Morey, 1935	×			
Bairdia fragosa Morey, 1935	×			
B. gibbera Morey, 1935	×	×		
B. magnacurta Morey, 1935	×	×	×	
B. pecki Morey, 1935	×			
B. subparallela Morey, 1935	×	×		
Bythocypris incertus Morey, 1935	×			
Pontocypris bassleri Morey, 1935	×			
Healdia subcarinata Morey, 1935	×			
Waylandella perplexa Morey, 1935	×			
Cytherella gunnelli Morey, 1935	×			
Sulcella decora Morey, 1935	×			
Hypotetragona impolita Morey, 1935	×		×	
Dizygopleura mehli Morey, 1935	×			
CHOUTEAU, MOREY, *1936*				
Amphissites similaris Morey, 1936		×	×	
Graphiadactyllis minutus Morey, 1936		×		
G. granopunctatus (Ulrich & Bassler), *in* Bassler, 1932		×	×	×
G. cornutus (Ulrich & Bassler), 1932		×	×	×
Kirkbyella ozarkensis Morey, 1936		×	×	
K. (?) dubia Morey, 1936		×		
Bairdia sinuosa Morey, 1936		×	×	
B. kinderhookensis Morey, 1936		×	×	
Acratia similaris Morey, 1936		×		
Silenites warei Morey, 1936		×	×	
S. marginiferus (Geis), 1932		×	×	
Healdia decora Morey, 1936		×		
FERN GLEN, BENSON, *1955; also identification by* ECHOLS & GOUTY				
Paraparchites sp.			×	
Tetrasacculus sp.			×	
Kirkbyella sp.			×	
Kirkbya fernglenensis Benson, 1955			×	
K. keiferi Benson, 1955			×	
Kirkbya sp.			×	
Amphissites centronotus (Ulrich & Bassler), 1906			×	
Roundyella mopacifa Benson, 1955			×	
Quassilites sp.			×	
Graphiadactyllis lineatus (Ulrich & Bassler), 1932			×	×
Graphiadactyllis fernglensis Benson, 1955			×	
Graphiadactyllis moridgei Benson, 1955			×	
Healdia sp.			×	
Bairdia aff. depressa Geis, 1932			×	
B. aff. citriformis Knight, 1928			×	
B. merivia Benson, 1955			×	
Waylandella sp.			×	
Coryellites sp.			×	
Bythocypris (?) sp.			×	
Microchoelenella (?) sp.			×	
RIDGETOP, BASSLER, *1932*				
Beyrichiopsis pulchra Ulrich & Bassler, 1932				×
B. modesta Ulrich & Bassler, 1932				×
Allostraca fimbriata Ulrich & Bassler, 1932				×
Aechmina longicornis Ulrich & Bassler, 1932				×
Ctenobolbina loculata Ulrich, 1890–1891				×
Mauryella mammillata Ulrich & Bassler, 1923				×
Bursulella? tennesseensis Ulrich & Bassler, 1932				×
Ulrichia tenuimuralis Ulrich & Bassler, 1932				×

that shifting currents over a shallow, intermittently muddy sea floor may have played an important role in sorting and distributing ostracode carapaces during the deposition of the Fern Glen. It is suggested that this type of faunal and sedimentary study might provide a basis for fairly detailed correlations.

BIBLIOGRAPHY

AGNEW, A. F., 1942, Bibliographic index of new genera and families of Paleozoic Ostracoda since 1934; Jour. Paleont., vol. 16, p. 756–763; Illinois Geol. Surv., Circular 86, 1942.

BASSLER, R. S., 1932, The stratigraphy of the Central Basin of Tennessee: Tenn. Div. Geol., Bull. 38, p. 1–268, pl. 1–49.

——, 1935, Descriptions of Paleozoic fossils from the Central Basin of Tennessee: Wash. Acad. Sci., Jour. 25, p. 403–409.

——, & KELLETT, BETTY, 1934, Bibliographic index of Paleozoic Ostracoda: Geol. Soc. Amer., Spec. Pap. no. 1.

BENSON, R. H., 1955, Ostracodes from the type section of the Fern Glen Formation: Jour. Paleont., vol. 29, p. 1030–1039, pl. 107,108.

BRADFIELD, H. H., 1935, Pennsylvanian Ostracoda of the Ardmore Basin, Oklahoma: Bull. Amer. Paleont., vol. 22, no. 73.

BRANSON, E. B., 1938, Stratigraphy and paleontology of the Lower Mississippian of Missouri: Missouri Univ. Studies, vol. 13, no. 3, pt. 1,2.

——, 1944, The geology of Missouri: Missouri Univ. Studies, vol. 19, no. 3, p. 1–535.

BRAYER, R. C., 1952, Salem Ostracoda of Missouri: Jour. Paleont., vol. 26, p. 162–174.

COOPER, C. L., 1941, Chester Ostracodes of Illinois: Illinois Geol. Surv., Rept. Investigations no. 77.

——, 1942, Occurrence and stratigraphic distribution of Paleozoic Ostracodes: Jour. Paleont., vol. 16, p. 764–775. Illinois Geol. Surv., Rept. Investigations no. 83.

——, 1946, Pennsylvanian Ostracodes of Illinois: Ill. Geol. Surv. Bull. 70, p. 1–177, pl. 1–21.

——, 1948, Kinderhook micropaleontology: Jour. Geol., vol. 56, p. 353–366.

CORDELL, R. J., 1943, Ostracodes from the Upper Pennsylvanian of Missouri. Part I; the Family Bairdiidae; Jour. Paleont. vol. 26, p. 74–112.

CORYELL, H. N., 1939, Mississippian formations of southern Illinois: Jour. Paleont., vol. 13, p. 203–310.

——, & BOOTH, R. T., 1933, Pennsylvanian Ostracoda: A continuation of the study of the Ostracoda fauna from the Wayland Shale, Graham, Texas: Amer. Midland Nat., vol. 14, no. 3, p. 258–283.

——, & JOHNSON, S. C., 1939, Ostracoda of the Clore Limestone of Illinois: Jour. Paleont., vol. 13, p. 214–224.

——, & MALKIN, D. S., 1936, Some Hamilton ostracodes from Arkona, Ontario: Amer. Mus. Novitates, no. 891, p. 1–20.

——, & SOHN, I. G., 1938, Ostracoda from the Mauch Chunk (Mississippian) of West Virginia: Jour. Paleont., vol. 12, p. 596–603.

CRONEIS, CAREY, 1939, Taxonomy of Chester ostracodes: Denison Univ. Bull. vol. 34, art. 2, p. 28–32.

——, & BRISTOL, H. M., 1939, New ostracodes from the Menard Formation: Denison Univ. Bull., vol. 34, art, 4, p. 65–102.

——, & FUNKHOUSER, H. J., 1939, New ostracodes from the Clore Formation: Denison Univ. Bull., vol. 33, art. 6, p. 331–360.

——, & GALE, S., JR., 1938, New ostracodes from the Golconda Formation: Denison Univ. Bull., vol. 33, art. 5, p. 251–296.

——, & GUTKE, R. L., 1939, New ostracodes from the Renault Foramtion: Denison Univ. Bull., vol. 34, art. 3, p. 33–63.

——, & THURMAN, F. A., 1938, New Ostracodes from the Kincaid Formation: Denison Univ. Bull., vol. 33, art. 6, p. 297–330.

GEIS, H. L., 1932, Some ostracodes from the Salem Limestone of Indiana: Jour. Paleont., vol. 6, p. 149–188.

HARLTON, B. L., 1929, Some Upper Mississippian (Fayetteville) and Lower Pennsylvanian (Wapanucka-Morrow) Ostracoda of Oklahoma and Arkansas: Amer. Jour. Sci., ser. 5, vol. 18, p. 254–270, pl. 1,2.

HENNINGSMOEN, G., 1953, Classification of Paleozoic straight-hinged ostracodes: Saertrykk av Norsk Geologisk Tidsskrift, vol. 31, p. 185–288.

KAISER, C. P., 1950, Stratigraphy of Lower Mississippian rocks in southwestern Missouri: Amer. Assoc. Petrol. Geol. Bull., vol. 34, p. 2133–2175.

MEHL, M. G. & THOMAS, L. A., 1947, Conodonts from the Fern Glen of Missouri: Denison Univ. Bull., vol. 40, vol. 5, art. 2, p. 3–20.

MOORE, R. C., 1928, Early Mississippian formations of Missouri: Missouri Bureau Geol. Mines, vol. 21.

——, 1948, Paleontological features of Mississippian rocks in North America and Europe: Jour. Geol., vol. 56, no. 4, p. 373–402.

MOREY, P. S., 1935, Ostracoda from the Amsden Formation of Wyoming: Jour. Paleont., vol. 9, p. 474–482.

——, 1935(a), Ostracoda from the basal Mississippian sandstone in central Missouri: Jour. Paleont., vol. 9, p. 316–326.

——, 1936, Ostracoda from the Chouteau Formation of Missouri: Jour. Paleont., vol. 10, p. 114–122.

PECK, R. E., 1936, Lower Mississippian Microcrinoids of the Kinderhook and Osage groups of Missouri: Jour. Paleont., vol. 10, p. 282–293.

SHUMARD, F. B., 1855, Geology of St. Louis and Franklin counties: 1st and 2nd Ann. Rept., Missouri Geol. Surv., p. 137–201.

SOHN, I. G., 1940, Check list of Mississippian Ostracoda of North America: Jour. Paleont., vol. 14, p. 154–160.

STEWART, G. A., 1936, Ostracodes of the Silica Shale, Middle Devonian, of Ohio: Jour. Paleont., vol. 10, p. 739–763.

—, & HENDRIX, W. E., 1945, Ostracoda of the Olentangy Shale, Franklin and Delaware counties, Ohio: Jour. Paleont., vol. 19, p. 96–115.

ULRICH, E. O., 1896–1901, New American Paleozoic Ostracoda: No. 1, *Ctenobolbina* and *Kirkbya:* Cinn. Soc. Nat. Hist. Jour., vol. 19, no. 6, p. 184.

—, & BASSLER, R. S., 1906, New American Paleozoic Ostracoda, notes and descriptions of Upper Carboniferous genera and species: U. S. National Museum, Proc., vol. 30, no. 1446, p. 149–164.

WELLER, STUART, 1909, Kinderhook faunal studies V, the fauna of the Fern Glen Formation: Geol. Soc. Amer., Bull., vol. 20, p. 265–332.

—, & ST. CLAIR, S., 1928, The geology of Ste. Genevieve County, Missouri: Missouri Bur. Geol. Mines, 2nd Ser., vol. 23.

WELLER, J. M., et al., 1948, Correlation of Mississippian formations of North America, Geol. Soc. Amer., Bull., vol. 52, p. 91–196.

WILSON, C. W. & SPAIN, E. L., JR., 1936, Age of Mississippian Ridgetop Shale of central Tennessee: Amer. Assoc. Pet. Geol. Bull., vol. 20, p. 805–809.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1324–1340, PL. 145, NOVEMBER 1956

TAXONOMY, NOMENCLATURE, ORIENTATION, AND STRATIGRAPHIC EVALUATION OF CONODONTS

KLAUS J. MÜLLER
State University of Iowa, Iowa City, Iowa

ABSTRACT—Conodonts are no longer regarded as teeth but rather as internal supporting elements of a nectonic animal, which may represent a separate class of the Chordata. There is a particular need for further investigations into the histology of the Neurodontiformes, as well as of the basal hard part in all groups. Also a search should be made for collecting localities that have specimens with exceptional preservation and which may disclose remains of soft parts. Assemblages have been found to be composed of 1–5 different types of conodonts, for which the term "partial-genus" is proposed, instead of the ambiguous expression "form-genus." A dual nomenclatural classification within the *Régles* is acknowledged as a practical necessity; several names for the same animal (as partial-genera as well as for the entire assemblage) could be accepted as valid by an opinion of the ICZN. The individual components (partial-genera) should be indicated in some simple manner.

Platform-type conodonts seem to be the best for stratigraphic purposes. A natural system of classification in this group may be attained by observation of transitional forms between related partial-genera. Not all assemblages contain platform-types, and the bars and blades have also produced reliable time markers.

Variation within a single animal (dextral and sinistral specimens), ontogenetic development revealed by growth lines, and variability within a population indicate that there is a considerable difference in form within the partial-species. For descriptions, arbitrary orientation by use of symbols (ABCD) is proposed, to facilitate comparison of homologues previously oriented inconsistently.

Conodonts are most commonly associated with fossil cephalopods, fish, and ostracodes. As a general rule, reef facies, as well as fusulinid limestones, contain few conodonts.

Cambrian conodonts from the Deadwood formation in South Dakota, the *Conaspis* zone in Utah and Wyoming, and from the *Agnostus pisiformis* and *Olenus* zones in northern Europe are recorded. The conodonts from the Signal Mountain formation in Oklahoma, previously regarded as Upper Cambrian, are similar to those from the lowermost Ordovician. Important index fossils and other representative conodonts are listed as examples from younger formations. The advantages and limitations of conodonts in stratigraphy are summarized.

INTRODUCTION

SINCE the classic investigations of Pander one hundred years ago conodonts have found increasing interest with paleontologists and stratigraphers. Many investigations have been published on this subject, particularly in the last decennium. Fay (1952) has prepared an accurate and quite complete catalogue, which lists the widespread literature, consisting of 620 papers up to 1949. Fay's compilations of the previously published material facilitate the work of new investigators considerably, and have already stimulated research in this group.

Our knowledge of conodonts from some portions of the Paleozoic and early Mesozoic is quite limited geographically, as conodonts are still virtually unstudied in most continents. Also many possibilities remain for improvement in systematics. Nevertheless, in the Ordovician, Devonian, Mississippian, and Pennsylvanian the status of knowledge is so far advanced, that applications in biochronology and stratigraphy can be attempted. Up to the present time, these possibilities have been little used; about the only reliance on conodonts has been in cases where other fossils are lacking or inconclusive. This review of the possibilities and limitations of conodonts in stratigraphy may assist to establish their value as index fossils.

ACKNOWLEDGMENTS

Professors A. K. Miller and W. M. Furnish have given editorial and advisory help in the preparation of this report. Dr. B. F. Glenister has loaned Australian conodonts for comparison. My stay in this country, on leave of absence from the Technische

Universität Berlin-Charlottenburg, has been made possible by a fellowship of the National Academy of Science-International Cooperation Administration. My wife, Eva Müller, has helped prepare the material, illustrations, and manuscript.

SYSTEMATIC POSITION OF CONODONTS

One of the most interesting but unexplained problems in paleontology is the systematic position of conodonts. More than one hundred papers deal with this subject, but even the most recent ones express diverse opinions. Rhodes (1954) has summarized and discussed prevalent and older ideas.

Gross (1954) has been able to exclude many of the previous interpretations by histologic-morphologic comparison of conodonts with Paleozoic agnatha and fishes; orientated thin-sections have been used for this study. His conclusions are (1954, p. 79):

1) Conodonts are not formed by a cuticula, as is the case in skeletons of arthropods and jaws of annelids. Those organs are secreted layer by layer from the epidermis-cells, and therefore become thicker toward the base.

2) Conodonts are neither mouth-teeth nor skin-scales of vertebrates. They are not composed of dentine, have no pulpa nor dentine channels, grow by outer instead of inner deposition, and are able to regenerate lost denticles as well as suppress others by the formation of germ denticles.

3) They are not a part of the endoskeleton of vertebrates. If so in the case of Paleozoic agnatha or fishes they would form an ossification around a cartilaginous core, and therefore as a fossil would surround a cavity, filled with sediment. Otherwise, they would have the spongy texture of cartilagenous tissue; such is not the case. Also, the shape is not as would be expected in parts of an endoskeleton. Therefore, conodonts cannot be a part of a gill apparatus, which belongs to the endoskeleton.

In addition, the following observations must be considered in establishing the true systematic position of conodonts:

1) Conodonts consist of a calcium carbonate-apatite, probably with a somewhat variable composition. Only the bones of vertebrates are composed of a substance with the same content. This fact is an important point, if not direct evidence for a systematic affinity with the vertebrates.

2) The vertical range of conodonts is known to be from the lower Upper Cambrian into the Middle Triassic. The early appearance indicates that conodonts may not belong to any known group of vertebrates, as none of the classes of known vertebrates have the same range as the conodonts.

3) The animal, in most cases, contains not only one generic-type but an assemblage of different forms of conodonts. The questions in connection with this observation are elaborated in one of the following paragraphs.

New facts, which possibly will give a further clue for determination of the systematic affinities of conodonts may be found by investigation of the following points.

1) By studying the histology of the Neurodontiformes Branson & Mehl. This group is confined to the Ordovician and seems to have a structure which is not yet known in detail and which is somewhat different from all other conodonts.

2) By histologic investigation of the base, (the hard part), which is often attached to the lower surface of conodonts, particularly on platform-types. This structure has been obviously formed by tissue other than that of the conodont. It has probably been built up by inner deposition of thin layers, in contrast to the conodont, which is built up by outer deposition. As in conodonts, regenerations may also have taken place on this hard part.

Stewart & Sweet (1956, p. 262) have described conodonts with a preserved base which is "opalescent to waxy in luster." This kind of preservation is typical in many bonebeds, but it is rare in other occurrences. These authors submitted a sample to McConnel who has determined the material of the bases as "collophane . . . [having] a lamellar structural arrangement and appears to be essentially isotropic, which is not characteristic of the conodont material itself." Even if his conclusions are based on material which has partly, or entirely, changed its composition, the fact remains that there is a clear difference between the conodont and the base.

3) Geological investigations in areas which may produce exceptional types of preservation, as in concretions or sediments formed in connection with evaporation shortly before the deposit of salt, may produce molds or even preserved body parts of the entire conodont animal. Trusheim (1937) has demonstrated on *Triops cancriformis minor* from the Keuper (=terrestrial Upper Triassic in middle Europe) that, in shales formed under evaporizing conditions just before or during the precipitation of salt, even the finest soft parts may be preserved as a thin film. The small size of the animal and the lack of hard parts, other than the conodont, would cause such fossils to be easily overlooked if one were not paying particular attention to this type of preservation and searching for remains of these organisms specifically.

NATURE AND COMPOSITION OF CONODONT ASSEMBLAGES

Conodont assemblages belonging to one animal have been described or mentioned by a number of authors (H. Schmidt, 1934, 1950; Scott, 1934, 1942; DuBois, 1943; C. L. Cooper, 1945; Rhodes, 1952, 1954, etc.). These authors have drawn their conclusions partly independently from each other on the basis of material secured from a variety of localities and of different ages. Their observations have been substantially the same, but their explanations differ widely. In any case, presence of natural assemblages is now confirmed by many workers.

Previous knowledge has been summarized by Rhodes (1954, p. 449): "Natural conodont assemblages appear to indicate that conodonts are paired, generally in an anteroposteriorly elongated arrangement. A single assemblage may contain 14–22 component conodonts, representing 3–5 different 'form-genera'."

However, in addition to the preponderant number of pairs there is also a minority of unpaired elements with bilateral symmetry. Representatives of this form-type (now probably to be classified with the genus *Roundya* Hass, 1953) have been found and described as *Hibbardella*-component by Rhodes, 1952, in *Duboisella typica* Rhodes. On all the figures of these assemblages (Rhodes, 1952, pl. 128, fig. 1,3,4) only one specimen of the form with bilateral symmetry is visible. Therefore, this component may not be paired as suggested in the reconstruction (Rhodes, 1952, p. 896, fig. 3). Obviously it has been arranged in the median line and for that reason it is possible that this type of assemblage has an odd number of components represented. In an abstract on conodont assemblages from a lower Kinderhook black shale, Cooper (1945) has regarded the *Hibbardella*-component as unpaired. The relatively rare occurrence of this generic type, compared with others in the same fauna may also be regarded as support for this opinion.

The composition of assemblages may have changed considerably during the phylogenetic development of conodonts. All assemblages described in detail have a preponderance of bar-types (e.g. *Hindeodella* and *Lonchodina*) in common. By contrast, in nearly all samples from the Upper Devonian the platforms far outnumber bars and blades together. One of the platform-types, *Palmatolepis*, constitutes in many cases about 40–50% of the entire fauna; the remainder composed of about 40 genera of different types. These proportions indicate that the composition of Upper Devonian assemblages is different from those described in Pennsylvanian rocks.

Most conodont faunas represent true biocoenose. In as much as acetic acid residues of limestones have preserved even the finest tips and processes, predominance of platform-types is not due to destruction of the more minute and brittle bar-types. Selective sorting according to size and shape may occur, but has not been observed in many hundreds of processed samples.

As might be expected, there are some cases in which the finer parts and elements of conodonts have been destroyed by abrasion. An example is found in the Genundewa (basal Upper Devonian) of Amsdell Creek, east side of Amsdell road, one half mile from the lake shore on Highway No. 5 at Wanakah, Erie County, New York. Mr. R. R. Hibbard has sent me a large sample from this locality which contains abundant conodonts. The more massive components, such as *Polygnathus linguiformis* Hinde and the main cusp of *Ligonodina recedens* (Bryant) predominate, and the usually associated minute forms are all lacking. These fossils have been transported and deposited, and nearly all specimens show signs of abrasion, in contrast to conodonts from cephalopod limestones.

In addition to the assemblages described with 3–5 different components, there have probably been assemblages consisting of only one "partial" generic-type. This is suggested by observation of some residues consisting almost entirely of one genus. A number of samples from Middle Devonian rocks have yielded several species of *Icriodus* and nearly no other conodonts. This form is widely distributed also in the Upper Devonian where, in most cases, it is represented only by a minority of specimens. However, in the Upper Devonian Sheffield shale of Iowa it is also predominant in the fauna (Youngquist & Peterson, 1947,

p. 242). This remarkable change of proportions presently has no equivalent in any other conodont genera.

Another example is found in the Signal Mountain limestone of the Arbuckle Mountains, Oklahoma. Several samples, collected from this formation near U. S. Highway 77 have yielded the genus *Cordylodus* nearly exclusively. Therefore, *Icriodus* and *Cordylodus* may be the only conodont types present in the particular animals.

Statistical analysis of the relative abundance of the form-types may serve for reconstruction of conodont assemblages. If in several stillwater deposits certain genera and species are always associated in about the same numeric proportion, they have probably belonged to the same natural species. The ratio of the remaining partial genera and species will differ between localities. Possibly in some cases some of them will be entirely lacking.

If an investigation of this type is to be done the fauna should be abundant and well preserved but composed only of few genera and species. Upper Devonian faunas contain a great number of genera and species and therefore are not well suited for this purpose. Better possibilities for material of this type would be for example in rocks of Silurian or Upper Mississippian age.

NOMENCLATURE OF CONODONT ASSEMBLAGES AND ELEMENTS

According to the International Rules of Zoologic Nomenclature, Art. 27a, the name of the first described part is valid for the entire animal. However, the application of this rule would be very difficult in the nomenclature of conodonts.

There are several distinct natural assemblages which contain the same form of conodont; by themselves they must be regarded as congeneric. *Hindeodella*, for example, has been found in three different assemblages, *Lewistownella*, *Lochriea*, and *Scottognathus*. Furthermore, *Lonchodina* is present in *Duboisella* as well as in *Illinella* (Rhodes, 1953a, p. 610). In connection with an assemblage from the Heath formation Scott (1942, p. 295) has commented: "This animal most probably is not congeneric with the genotype on which the oldest form genus was originally based, and to call it by that generic name and to reduce the other names to synonyms, as would be required by the International Rules, not only would be improper but would result in utter confusion."

In his studies on Upper Devonian Polychaetes, Lange (1949, p. 53) has reached similar conclusions. He states: "Though perhaps not specifically identical, several forms similar to the different parts of the articulate jaw apparatus of *Paulinites paranaensis* [*i.e.* a name given by him for the entire assemblage] have been assigned to nine distinct genera."

Scott, Rhodes, and Lange have proposed new names for the assemblages. Parts named previously are either relegated to anatomical terms (hindeodells or prionids), or, in the case of scolecodonts, omitted. Lange prefers terms used in zoology such as forceps, dental plate, etc. In the description of assemblages this nomenclatorial procedure seems to be quite adequate.

However, in stratigraphic paleontology the use of a name for the entire assemblage is not practicable with conodonts or any other fossils which are isolated parts of skeletons. In biochronology and stratigraphy the description of single elements is unavoidable as only these are available for this type of work. Even if the true relationship and systematic position of these isolated parts could be known, practical paleonologists would not find it desirable to apply the name of the entire assemblage for part of it. Such a use would involve many uncertainties due to the interpolation of knowledge obtained from sources other than the fossils under study. In most cases identification of the species would necessarily precede determination of the genus. This procedure may be proper for work in zoology or paleozoology, but is certainly not recommended in stratigraphic paleontology.

A system based on known assemblages and applied to the isolated elements as in conodonts cannot be established at the present time, as the facts are too scarce. When, eventually, a system of classification based on assemblages can be attained it may be of no advantage to the geologist and stratigrapher. In addition, it will be necessary to change the meaning of all names previously applied to conodonts, a justifiable procedure only if important new viewpoints are obtained.

Dual classification of conodonts within the framework of the *Régles* of nomenclature (Scott, 1942; Rhodes, 1952, 1953; Sylvester-Bradley, 1954; Frizzell & Exline, 1955) seems to be the best solution of this nomenclatorial problem. Since it is not desirable that a fossil may have more than one valid name [*i.e.*, one as an assemblage and several as partial components], it is proposed that the names for the parts be marked in a simple fashion. A preceding degree sign or superscript lower case letter "o," *e.g.* °*Palmatolepis* (*Palmatolepis*) *perlobata* Ulrich & Bassler, 1926, would indicate that this is a partial component which may or may not be a part of a described animal. Discussion of possible affinities of such a disjunct part should be given in the text. In the same way tracks of fossils which in some cases are also valuable index fossils of unknown affinity can be named. This marking may also be applied to otoliths, onychites, aptychi and opercula, scolecodonts, holothurian sclerites, sponge spicules, etc.

At the present time this procedure is not permissible according to the International Rules of Zoological Nomenclature, but it may become so by suspension of Art. 27a for particular groups or purposes. For the sake of stability of nomenclature within a particular group, such as conodonts, the suspension may be granted by the International Commission, following submittal of a formal application.

After writing this discussion I received a copy of an "Application for a declaration recognizing parataxa as a special category for the classification and nomenclature of discrete fragments or of life-stages of animals which are inadequate for identification of whole-animal taxa, with proposals of procedure for the nomenclature of parataxa," to be submitted to the International Commission for Zoological Nomenclature by R. C. Moore & P. C. Sylvester-Bradley. It is hoped that this application will find the approval of the Commission. The "partial genera" and species of this paper are "parataxa" in the sense of Moore & Sylvester-Bradley.

Nomenclature is a technique for communication and it has to be adapted to the developing demands of taxonomy as far as possible within the previously established rules. It is contrary to the basic aims of nomenclature, that either observations or ideas on taxonomy are to be suppressed because there is no *proper* way for their expression. However, application of the present rules would result in such instability of names that Lindström (1954, p. 541) has remarked: "to put it drastically, it will be in the interest of micropaleontologists to find as few conodont assemblages as possible!"

FORM-GENERA AND PARTIAL-GENERA

Previously the term "natural genera" has been applied for the conodont assemblages and "form-genera" for the single conodonts. The first term is understandable, if somewhat ambiguous, because it does not say anything about the position in a "natural system" but means an integral genus. The latter however has been applied in so many senses that it should not be used for the meaning under discussion. Shimer & Shrock (1944, p. 1,2) have given three different meanings for the term "form-genus":

> 1) For a series of related genera which have resulted from the splitting up of an old familar genus, as *Fusulina*, *Aulopora*, *Productus*, *Platyceras*, and *Dikelocephalus*.
>
> 2) It may be used for a complex of genera which are known to be distinct but which have not as yet been named because all have the same general habit. Examples are *Tetragraptus* and *Monograptus*.
>
> 3) It is a general designation for the residuum after a genus has been partly revised. Examples are *Zaphrentis*, *Orthoceras*, and *Calymene*.

In addition, the term has been applied to a morphologic group instead of a phylogenetic unit.

What has been understood as "form-genus" in conodonts does not fit any of the above mentioned definitions. Therefore the term "partial-genus" is proposed here with the same meaning as "form-genus" as used by Rhodes (1952, p. 889). This seems necessary, because a partial-genus may be a form-genus in all of the senses defined by Shimer & Shrock. Accordingly, the term form-species is to be replaced in this meaning by partial-species.

CONCEPT OF PARTIAL-SPECIES

Conodont assemblages in most cases are

composed of several partial-species, with quite different values as time markers. Ellison (1946) and Beckmann (1953) have noted that generally the platform types are good index fossils. However, this particular time sensitivity of platform types seems to be in relation to their systematic significance. Even if the entire animal is known, systematics still must rely on those parts which show the most significant evolutionary changes. Therefore, the systematic value of isolated platform types may be compared with teeth of mammals, which often may serve alone to distinguish genera and species. For this reason I believe that a modified classification of isolated platform types would not differ much from a system based on the entire assemblages containing these, in addition to others. Obviously, not every type of assemblage had platform elements, and it is therefore inadvisable to confine the study to this type. Within the bars and blades there are also short ranging genera such as: *Pinacognathus*, *Diplododella*, *Apatognathus*, *Subbryantodus*, *Elsonella*, *Scutula*, and *Tripodellus*. In general, our knowledge of these forms is relatively limited.

Even in the long ranging partial-genera there are further taxonomic possibilities, which eventually may lead to a better application in biochronology. As has been demonstrated by Rhodes (1954, p. 435), Scott (1934, 1942), and others, the same partial-genera may occur in different assemblages. This fact deserves recognition in taxonomy of isolated conodonts. Ellison's (1946, p. 94–95) charts on the stratigraphic range of conodonts show genera, such as *Hindeodella* and *Lonchodina*, to have particularly long ranges. Their shape may correspond to a certain function within the body, and present systematic understanding may be compared with the "humerus" in vertebrates (the humerus has a range Devonian-Recent, comparable to *Hindeodella*, Ordovician-Triassic). Recognition of a bone as a humerus does not exhaust its value as an index fossil. In many cases there are recognizable differences of stratigraphic significance in humeri of even related genera. In *Hindeodella* there is a similar situation, although differences between the types are not as pronounced.

The decisive factor for defining partial-species is the presence of readily visible morphologic differences; systematics can be based on these only. An alternative between splitting into several new partial-genera or division into subgenera will be decided by the probable importance of the dissimilarity. Subdivision of the long ranging genera into subgenera seems to me to be the most practicable solution.

For example, it is possible to distinguish two taxonomic units within *Hindeodella*, the differences being on the B (posterior) end. It is in some cases hook-like and deflected downward, and in others the last denticle is slightly bowed upward. This difference has stratigraphic significance, but on most specimens the distinguishing part is broken off. If this feature would be regarded as constituting a generic difference in many cases the genus would be indeterminate although the species might be distinguished from preserved features. Many previously described species could not be recognized as belonging to one or the other of the genera on the basis of fragmentary type specimens. However, the B-(posterior) feature is regarded as constituting only a subgeneric difference, the name can be expressed easily if necessary, by conveniently omitting the subgenus.

In some cases abnormal growth (pathologic development or teratism) of conodonts may develop forms which are difficult to determine. Sannemann (1955, p. 124) has observed pathologic bifurcation of branches on *Bryantodus*, *Hindeodella*, *Ligonodina*, *Ozarkodina*, and *Palmatolepis*. Correspondingly, in his opinion *Centrognathodus* Branson & Mehl, 1948 [= *Centrognathus* Branson & Mehl, 1934, *non* Guérin-Méneville, 1840] is perhaps only a pathologic *Hindeodella*. However, I have seen several representatives referred to one species of *Centrognathodus*, in which the bifurcation has about the same position on every specimen. This is evidence for the validity of a generic distinction from *Hindeodella*.

Some figures of *Palmatolepis*, given by Ulrich & Bassler (1926) have been regarded by Sannemann (1955, p. 124) as deformed. Reexamination of the poorly preserved originals of Ulrich & Bassler shows that these are normal specimens, and the strange form is due only to preservation——the original of their Plate 7 figure 4, shows part of a second conodont attached to the C-ward

process. An example of a deformed *Palmatolepis* is figured (Pl. 145, fig. 9–11). Such abnormities are relatively rare and only about one in a thousand has been found in my extensive collections of this genus.

NATURAL AND UTILITARISTIC SYSTEMATICS OF PARTIAL-GENERA

Lindström (1954, p. 539) has remarked in his important paper on conodonts from the lowermost Ordovician in southern Sweden: "the object of the classification of isolated conodonts could not be to expound phylogenetic relationships between the different kinds of conodonts. Classification of isolated conodonts rather has to restrict its aims so as to provide the worker concerned with conodonts, especially in the field of stratigraphic geology, with clearcut morphological cathegories."

However, it may be mentioned, that a phylogenetic arrangement of taxa forming a natural system can be based only on morphologic similarities and differences; these form the only criteria available in systematic paleontology. The differences between a morphologic and a natural concept in systematics is given by "the interpretation of morphological similarities and differences in terms of probable phylogenetic significance" (Weller, 1949, p. 683). Unavoidably this interpretation will be somewhat subjective. Also, any morphologic system inevitably contains personal opinion. Out of the present large number of features, only a few are selected and on the basis of these the system is established. In many cases the decision as to whether a specimen belongs to the one group or the other may be the mere judgment of the student.

A phylogenetic concept stresses the evolutionary trends within the group and may be useful in formulating a decision if forms are related or if similarity is due to convergence. An example may be the chart "geological history of conodont types" by Rhodes (1954, p. 437). In addition to mere morphologic similarities a form group "lachryform platform types" has been assembled: *Iriodina* in the Lower Silurian, *Icriodus* in the Middle-Upper Devonian, and *Gondolella* in the Middle Pennsylvanian-Lower Permian (also in Middle Triassic). In the time intervals between the occurrences of the listed genera no lachryform platform types are noted. In addition, there is no close relationship between these genera, but merely a similarity in shape. The genera by themselves are good time markers, but the group together has little meaning in stratigraphy.

A method for recognition of phylogenetic relationship is the observation of transitory links between the partial-genera. Numerous examples have been given by Branson & Mehl (1933–1934). Huddle (1934, p. 26) has described the development of *Polygnathus* from *Ctenognathus*. Ellison (1946, p. 96) has noted all gradational forms from *Ctenognathus* to *Gnathodus*, from *Prioniodina* to *Gondolella*, from *Ozarkodina* to *Solenodella*, etc. According to Rhodes (1952, p. 893) there are transitional forms between *Streptognathodus* and *Idiognathodus*. Further examples are the development of *Palmatolepis* and *Siphonodella* from *Polygnathus*.

The best possibilities for recognition of a natural system are within the platform types. These have been transformed more than most other forms in their evolution and therefore have produced many good index fossils.

A phylogenetic system also seems to be desirable for the single cones, blades and bars. The relationship between the different partial-genera and species will be more difficult to recognize, however. These often have no well marked changes in the course of evolution. Nevertheless, recognition of evolutionary trends in even less important parts or organs may lead to new and important view-points. A system in stratigraphic paleontology, particularly of such isolated parts as conodonts, should be an aid in determination. For the bar and blade types, therefore, it will be necessary to compromise between a natural and a utilitarian system.

CONCEPT OF PARTIAL-SPECIES

The amount of variability within a species may be determined by a combination of several methods:

Variation within a single animal.—Rhodes (1952, p. 889, pl. 127, fig. 5–6,11–12; pl. 129, fig. 2) has figured pairs of conodonts which have been isolated from natural assemblages. The remarkable difference in sculpture between

dextral and sinistral specimens of *Streptognathodus excelsus* Stauffer & Plummer (pl. 127, fig. 5–6) may be useful to indicate the amount of probable variability in such cases where assemblages are unknown. Unfortunately nothing has been published on the variability of the bar and blade types within an assemblage, and only very little is known about the other genera. Amplification of the variability within a single individual seems worthy of further investigations.

Most conodont assemblages consist of several partial-species, which may be represented by more than a single pair of specimens within the animal. From the published illustrations of assemblages, it seems that there are no differences between the pairs, e.g. of *Hindeodella*. However so little is known of the composition of assemblages, that no generalization may be allowed yet. It seems possible that in some cases there may be differences between pairs of conodonts in an assemblage, which constitute different partial-species, if noted in dissociated specimens.

Ontogenetic transformation.—Investigations on the histology of conodonts (Hass, 1941; Gross, 1954) have demonstrated that the growth lamellae of conodonts are not exactly parallel to each other, but are somewhat variable in their width. New denticles originate and others are transformed to germ denticles by overgrowth. In some cases a change in the direction of growth also occurs. This relationship can be observed in well preserved specimens without thin sections. The rim may show a lobation which is merely accidental, having originated by a local failure of growth; later the lobe may be filled again by more widely spaced growth lamellae. Other changes of growth pattern can be noted which are related to the size of the conodont. For comparisons it is therefore essential to select specimens of the same size, or at least to take into consideration the change of shape during growth. As has been observed, this is true for the outline as well as for the sculpture of the platform in *Palmatolepis* (Müller, 1956).

Variation within a population.—Statistical investigations on a single partial-genus from an abundant horizon have shown that there are transitional stages between forms which individually are quite distinct. If, in other occurrences, lack of sufficient material does not allow an investigation of the amount of variability, it seems essential to apply the experience gained in similar cases and accept a broad concept for species, *i.e.* regard the few somewhat aberrant specimens as conspecific.

In most cases a fairly well defined species concept thus will be attained. Specific differences which can be established in an early stage of ontogony seem to be particularly well suited for definition. These features are useful for comparison of different growth stages. An example is the gradual transformation recognizable on even very small specimens, of a straight into a sigmoidal keel. In this fashion it is possible to distinguish the following related species from each other: *Palmatolepis* (*Manticolepis*) *transitans*, *P.* (*M.*) *martenbergensis*, and *P.* (*M.*) *triangularis*. These three species probably form a phylogenetic series.

Often it will be impossible to recognize an atypical conodont specimen as belonging to a previously established species, if only the holotype has been described and figured. Therefore, in the description of species, remarks on the range of the variation of the more important features are essential. Figures of extreme variants are particularly helpful in identification of the species.

ORIENTATION AND MORPHOLOGIC TERMINOLOGY

There seems to be general agreement concerning orientation of conodont-elements for the purpose of description:

1. Conodonts with right-left symmetry are arranged lengthwise, *i.e.* in the direction of their most prominent growth. Any other orientation for the bars and blades would hardly be understandable. The alternation between denticles of first and second order, as demonstrated in some species of *Hindeodella*, reminds one of metamerism.

2. The side which bears denticles has been regarded as upper or "oral" and the other as lower or "aboral." The histology (Hass, 1941; Gross, 1954) indicates clearly that conodonts cannot be mouth-dentures. Therefore, the terms oral and aboral should be avoided.

3. In previous studies, in single cones as well as compound forms with bilateral symmetry, the convex side of the cone or main denticle has been regarded as anterior.

In some cases there are exceptions to these usages. However, in order to facilitate comparisons of features, a uniform orientation has to be maintained within the same genus.

Some disagreement exists on the recognition of anterior and posterior in conodont-elements. Consistent orientation of homologous parts must be attained in order to recognize transitional forms between the genera. The question of anterior or posterior position is of minor importance in this respect.

Inconsistencies of orientation in conodont elements are numerous in the literature. A typical example is that of the group *Prioniodus-Dichognathus-Neoprioniodus-*

Prioniodina-Lonchodina-Gondolella, between which transitional forms exist. In *Prioniodus*, *Dichognathus*, and *Neoprioniodus* the main cusp and basal cavity have been regarded as anterior in previous literature. In *Prioniodina* the denticles are directed toward the smaller end. In the original descriptions of the species, Ulrich & Bassler (1926, p. 18) have avoided the use of terms anterior and posterior and have designated only a "shorter end." However, the anterior end of *Neoprioniodus* is analogous, for some species of this genus have denticles directed "anteriorly."

Branson & Mehl (1934, p. 213) recognized that *Lonchodina* is closely allied to *Prioniodina*. In *Lonchodina* the orientation is so that the denticles recline "posteriorly" and is therefore just opposite to *Neoprioniodus*. Furthermore, in some representatives of *Lonchodina* the denticles are curved toward the inner side. This seems to indicate that the position of this element has been turned in the course of evolution, and the ends may have been lateral in position. In this case the designation of one end as anterior would not be in agreement with its true position. *Gondolella*, which originated from *Prioniodina* (Ellison, 1946, p. 96), has been orientated like *Lonchodina* and opposite to *Neoprioniodus*.

In the original description *Pelekysgnathus* (Thomas, 1949, p. 424), was orientated opposite to the similar *Icriodus*. The two genera are probably closely related, and the main denticle should be designated the same in each case.

Ellison (1941, p. 127) has recognized the difficulties of comparison between similar genera resulting from different orientation. Therefore he proposed a change of orientation in *Streptognathodus* Stauffer & Plummer, and *Idiognathodus* Gunnel. The improvement thus attained has been accepted by subsequent authors. This reorientation represents important progress in the comparative study of conodonts. Nevertheless it has the disadvantage of introducing inconsistency between the descriptions in different papers. The tip of the platform of *Streptognathodus* and *Idiognathodus* has been designated (Gunnel, 1931); Stauffer & Plummer, 1932) as anterior. Ellison and his followers have regarded it as posterior.

The true orientation of many conodonts in the body of the conodont bearing animal seems to be an open question. It has been accepted that the denticles for the bars and blades are curved or inclined posteriorly (Ellison, 1946, p. 98). In many cases this may be true. However, some conodonts such as *Gondolella* may have been arranged not parallel to the body of the animal but in an acute or obtuse angle to its axis. In most species of *Neoprioniodus* the denticles are directed somewhat "posteriorly"; in some cases, however, they are straight, and in others they are inclined "anteriorly." A change of the angle between body axis and axis of the individual conodont seems a more probable explanation than reversion of the entire conodont unit.

The blade of the family Gnathodontidae, as well as the other platform types, has been regarded as anterior (Ellison, 1946, p. 98; Rhodes, 1952, 1953, and others). Hass indicates by orientation of his figures that he would prefer just the opposite. He compares the basal cavity with its equivalent in *Prioniodus* (confirmed by oral communication, Nov. 1955). The Gnathodontidae were derived from *Ctenognathus*, where the basal cavity as well as the flanges are in the middle of the blade. The migration of these features either forward or backward seems to be possible.

The question does not necessarily need to be decided in order to obtain uniformity of orientation in the descriptions. Consistency may be attained by omitting the interpretative terms "anterior" and "posterior" and substituting mere symbols, such as "A" and "B." In this way it would be possible to describe homologues with the same symbol, even if the orientation in the body has been changed in the course of evolution. The terms anterior and posterior would no longer be used in the descriptions, but the true position may be discussed. Also the use of the symbols would tend to reduce confusion resulting from reorientation.

Similar considerations are true for the designation of the inner and outer sides. Therefore it is suggested to substitue "C" for the side which has been designated as "inner" (Müller, 1956) and which in most cases is the more strongly developed side in platform and related types. Accordingly the opposite or outer side will receive the symbol "D."

The homologues in many cases are obvi-

ous and easy to recognize. A nearly general agreement has been attained in most of these cases in previous literature; *e.g.* in Gnathodontidae and Polygnathidae. Other common genera are little understood at the present time, and it may be expected that the following preliminary suggestions for orientation are to be modified later when these forms are better known. The main purpose of the following proposals is to draw attention to the question of homologues.

In single cones (Distacodidae) the convex side of the cone may be regarded as A and the concave side as B. Most probably in this case the A side has been anterior in the body.

Cordylodus [=*Subcordylodus*], *Belodus*, *Cyrtoniodus*, *Microcoelodus*, and *Loxodus* obviously have been derived from single cones by development of a denticulate branch on the B-side. The main cusp is therefore regarded as A. *Holodontus*, *Trapezognathus*, and *Pteroconus* may be oriented in the same fashion.

Strachanognathus, however, has been differentiated differently and the smaller cone is on the A-side.

Compound conodonts with bilateral symmetry (Hibbardellidae) have developed from bilaterally symmetrical single cones. Therefore, the convex side of the main denticle has to be regarded as homologous to the A-side of the Distacodidae. The opposite side, which may have a median branch is therefore designated as B.

Under a modification of the previous system (Branson & Mehl, 1944) the family Prioniodidae is here redefined as a group consisting of closely related forms, mostly bar types. It includes *Prioniodus*, *Dichognathus* [=?*Gothodus*], *Tetraprioniodus* [=*Rosagnathus*], *Keislognathus*, *Periodon* [=*Phragmodus*], *Neoprioniodus*, *Prioniodina*, *Lonchodina* (part), *Euprioniodina*. The end with the basal cavity or scar, as well as the main cusp or main denticle and/or the smaller branch of the bar, are regarded as homologous of the convex side in the Distacodidae, from which all these forms may have developed. In the same manner *Synprioniodina*, *Metalonchodina*, *Subbryantodus*, *Oulodus*, and *Falcodus* may be oriented.

In *Hindeodella*, *Ligonodina*, *Angulodus*, and similar forms, side A is also designated as that with the smaller branch; this shorter element may be directed toward C. The orientation of *Bryantodus*, *Nothognathella*, *Polygnathellus*, *Lonchodina* (part), *Ozarkodina*, *Palmatodella*, *Plectospathodus*, *Pinacognathus*, and similar forms, is somewhat doubtful. Probably the larger branch should be regarded as the A side as the denticles are inclined toward B.

On platform types with a blade (Polygnathidae and Gnathodontidae) the blade is designated as A and the plate as B-side. *Icriodus* and *Pelekysgnathus*, however, may be oriented with the basal cavity and main cusp toward A.

ECOLOGY OF CONODONTS

Conodonts occur in marine sediments. I have not been able to investigate if they are also present in limnetic deposits. Branson & Mehl (1934, p. 362) are not committed on this question: "some of them may have lived in fresh or brackish water." However, in the Pennsylvanian cyclic sediments of the upper Mississippian Valley region, conodonts seem to be confined to the marine beds.

If the occurrences typified by secondary deposition as well as colluvial accumulations are excluded, a general rule may be recognized for abundance: the slower the rate of sediment accumulation, the better chance for preservation of a good fauna. Therefore, the chances of obtaining good conodonts are much better in limestones and fine grained shales than in sandy shales, sandstones, or conglomerates.

Quite commonly conodonts are associated with cephalopods. This is particularly true for the cephalopod limestones which have yielded conodonts in about 80% of all cases investigated. Shales with cephalopods often produce conodonts also, even though the macrofauna may consist largely of other fossils. Furthermore, they have commonly been observed together with ostracodes.

As has been pointed out by Youngquist (1952), conodont associations with fish remains are very common. This author has given a number of examples from previous literature. Many marine bone beds, particularly in the Midwest and Eastern Interior, have yielded conodonts. Therefore, Rhodes' (1954, p. 433) study of the Upper Silurian Ludlow bone bed, "which is composed almost entirely of fragments of fossil fish, [and] has not yielded a single cono-

dont," seems to be an exception. Harley (1861) had previously found conodonts in this layer and Volborth (1861, p. 464) notes that he has secured "hundreds of conodonts" from an iron oxide rich, disintegrated, black-brown, soily layer of the bone bed near Ludlow. Also in a bone bed in the *Beyrichia* limestone, a glacial erratic in northern Germany, conodonts of a similar age are quite common.

It should be emphasized that the distribution of conodonts is much wider than that of cephalopods, ostracodes, and fish remains. They are, for example, quite common in black shales in which no other fossils except phosphatic brachiopods are preserved. Conodont assemblages which can only be preserved under stillwater conditions have also been found in this type of facies.

Abundant corals, crinoids, and brachiopods seem to be unfavorable for association with conodonts. In some cases however, such as the Desmoinesian and Middle Ordovician (Guttenberg) of Iowa conodonts have been found in brachiopod coquinas. Fusuline limestones and marls contain few conodonts, a generalization based on about 20 samples of different origin. Reefs of corals, stromatoporoids, algae, and sponges contain conodonts only rarely, and the few specimens found in this type of environment may be accidental.

The wide distribution over many different types of facies may be regarded as evidence that the Conodontida belonged to the nekton. This has been assumed previously by Ruedemann (1934, p. 41,42) and Ellison (1944, p. 2). The worldwide distribution of conspecific conodonts may be regarded as additional evidence. Furthermore, the bilateral symmetry of the conodont animal suggests active mobility.

Practically nothing is yet known on the occurrence of genera in relation to facies. In the Upper Devonian I have noted a strong change of the relative abundance of partial-genera which obviously is not due to different age. The observations, however, are not sufficient to draw conclusions and this change could be a mere random distribution.

GEOGRAPHIC DISTRIBUTION OF PARTIAL-SPECIES

The decisive point for establishing a partial-species is the presence of one or more morphologic differences which are recognizable in at least a few specimens. That the range of variability in conodonts is relatively great has already been discussed in the preceding pages. The concept of species thus may be somewhat more comprehensive as it is in zoology, because only disjunct hard parts of the animal are available for comparison. This same limitation is also true for many other fossils.

By comparison of material from Europe, North America, and Australia it has been established that often the geographic differentiation is less marked than the range of variation within a species. In some cases there is no recognizable difference between specimens from the different continents. All the more recent students of European conodonts (*e.g.* Beckmann, Lindström, Rhodes, Sannemann) have determined at least part of their material as being conspecific with North American forms.

An example of regional differentiation has been observed in the group of *Palmatolepis* (*Manticolepis*) *subrecta* (Miller & Youngquist), and *P.* (*M.*) *triangularis* (Sannemann). The first species has been found in shales and limestones of the early Upper Devonian in North America, whereas the latter is quite common in limestones of the same age in Europe. In single specimens a difference between the two species can hardly be defined. However, the maxima of variability do not coincide, and therefore the species are doubtlessly distinguishable in abundant material. In this case the concept of each species is particularly wide, and I have maintained both of them. However, it seems to be questionable if it will be practicable to retain both names. A distinction from the geographic position of the locality, either in Europe or in North America, seems inadvisable. The distinction of taxa in paleontology must be based on morphologic differences alone if a true comparison between continents, environments, and ages is to be accomplished.

The close similarity of faunal aggregates between localities in different continents, particularly Europe and Australia where abundant cephalopod faunas are associated with conodonts, indicates that the two were deposited at the same time.

VERTICAL DISTRIBUTION OF CONODONTS

The oldest conodonts.—Lowermost Ordo-

vician strata contain the oldest conodont faunas which have been noted. These are relatively well known, due to the investigations of Pander (1856), Furnish (1938), and Lindström (1954). The first indications of an occurrence of conodonts in older formations were noted in the summer of 1955, on a field trip to the Arbuckle Mountains in south central Oklahoma. In the lower part of the Arbuckle group samples of limestone were secured which have yielded about 100 well preserved conodonts.

The section of the Arbuckle group in the Arbuckle Mountains on U. S. Highway 77 consists of the following formations (thicknesses after Decker & Merritt, 1928):

overlying:	Joins limestone (Simpson group)
5636′	West Spring Creek formation Kindblade formation Cool Creek formation McKenzie Hill formation
1472′	Butterfly dolomite
289′	Signal Mountain limestone
~500′	Royer dolomite
98′	Fort Sill limestone
underlying:	Reagan sandstone.

The boundary between Cambrian and Ordovician has been assumed to lie beneath the McKenzie Hill formation (Howell *et al.*, 1944), but Dr. A. R. Palmer has told me that he is not convinced of this correlation, because in the upper Signal Mountain limestone there are fossils present, which elsewhere are believed to be characteristic of the lowermost Ordovician. The conodonts have been secured from four horizons in the upper part of the Signal Mountain limestone. The predominating partial-genus is *Cordylodus*, but rare *Drepanodus* is also present in the material. Both genera are common and widely distributed in the lowermost Ordovician, but the forms do not belong to any of the previously described species.

The common occurrence of such a highly developed compound conodont as *Cordylodus* in this formation made it probable that there would be conodonts in still older rocks also. Therefore, I processed material from available sediments of Upper Cambrian age in which the lithology seemed favorable for the presence and preservation of conodonts. The best results have been from material from the Deadwood formation of the Black Hills, South Dakota.

The youngest faunule comes from near the top of the formation and may be Lower Ordovician. It contains *Drepanodus* which is lacking in all the lower beds.

The Cambrian age of the following samples, however, has been proved by associated trilobite faunas.

1. Limestone from first ridge southwest of Whitewood Peak, Black Hills. This sample has produced only a few conodonts.

2. Material from the shale-limestone-limestone conglomerate sequence on Little Elk Creek. A fauna has been found in two horizons within this member and is excellently preserved. None of the Deadwood genera have been found either in the Ordovician or the Signal Mountain limestone. There are no compound conodonts. All the forms present have a large basal cavity, which in some cases is almost as wide as the length of the entire conodont. Nearly all the specimens are bilaterally symmetrical or subsymmetrical. In later formations, bilateral symmetry also occurs, but is not as common as in these samples. There seems to be no great variety, the 53 specimens from the Deadwood formation may be referred to only 3 genera.

As in Ordovician single cones, the shape of the basal cavity seems to be the most important feature for taxonomy in Cambrian conodonts. Triangular as well as quadrangular, almost quadrate, cross sections can be observed. The large size of the basal cavity in Cambrian forms could have been anticipated for it has been observed to reduce progressively during evolution. Triassic conodonts have almost no basal cavity (Müller, 1956).

Other conodonts have been secured from the *Agnostus*-limestone (locality: Altüttendorf, Mark Brandenburg, Germany) and from the *Olenus*-limestone (locality: Berlin Blankenfelde). In both cases the rock is a black bituminous limestone of Upper Cambrian age consisting of a coquina of trilobite fragments. These Cambrian limestones were obtained by Mr. Lehmann, Berlin Neukolln, from drift deposits.

The most characteristic form from the *Agnostus*-limestone is a single conodont, the tip of which has a distinct recurvature. Rhodes (1953b, p. 291) has figured Ordovician *Drepanodus* with a recurvature of the tip which, however, is not as strong as in the material from the Cambrian. Furthermore, there is a form with a large triangular basal cavity similar to one from the Deadwood formation. The same genera as those in the *Agnostus*-limestone are also present in the *Olenus*-limestone, probably with other species. From each formation there has been

available only less than 100 grams of limestone; therefore, the material secured consists of only 15 specimens.

Dr. A. R. Palmer has given me two small samples of limestone from the Middle Upper Cambrian *Conaspis* zone which also contain conodonts. A dense, gray, red-mottled limestone from the Conant Creek area, Fremont County, Wyoming, NE¼, Sec. 13, T 32 N, R 94 W, has one genus in common with the Deadwood formation. Another sample is a dark gray crystalline limestone with numerous fossil fragments, the *Eoorthis* subzone of the *Conaspis* zone from the Dugway Mountains, Utah. Forms characterized by large quadrangular or triangular basal cavities appear congeneric, if not conspecific, with those from the Deadwood formation.

My conclusion that the fossils under consideration are conodonts has been derived from the following observations:

1. They have generally the same shape as the single cones of the Ordovician. Also like these, they have a basal cavity and a more or less curved tip.

2. They have the same structure as single conodonts. A few specimens show the typical growth lines in transmitted light, a characteristic observed as early as 1856 by Pander (*e.g.* pl. 3, fig. 4) on younger forms.

3. The size is only slightly smaller than that of Ordovician conodonts.

4. In most cases the preservation is the same as in younger conodonts. This seems to indicate that they may consist of the same material.

W. M. Furnish, who is acquainted with Lower Ordovician forms, has seen the Cambrian material and believes that they are conodonts.

A different preservation was observed in one horizon from the Deadwood formation and in the above mentioned sample from the Dugway Mountains. In these cases a transformation has probably taken place by diagenesis into a sericite-like mineral.

Since it is planned to study these forms more extensively, other samples from well correlated Upper Cambrian limestones are solicited by the author.

PHYLOGENETIC DEVELOPMENT AND TYPICAL EXAMPLES OF YOUNGER EPOCHS

Some of the more important generalizations on conodont research which may be applied to stratigraphy can be summarized. The examples given are of relatively common distinct forms. They have been selected as most suitable for an introductory analysis of the group. Because not many detailed investigations have been published, the full possibilities for application in biochronology and stratigraphy are not yet realized.

The first strong development or acme of conodonts was in the Ordovician. The fauna of this period is characterized by an abundance and diversity of single cones (Distacodidae). Taxa are distinguished chiefly by the cross section of the basal cavity. Typical examples are *Oistodus* (with a sharp angle between the base and cone) and *Distacodus* (with bilateral symmetry of the basal cavity). The Neurodontiformes are a group of predominantly compound conodonts with somewhat distinct (fibrous) structure which has not yet been studied sufficiently. They seem to be confined to the Ordovician; a typical example is *Amorphognathus* (platform type with 5–7 lobes). In the Arenig the first compound conodonts with bilateral symmetry have been found; an example is *Trichonodella* (without median branch and with wide basal cavity). Subdivision of the Ordovician into stages and even zones on the basis of conodont species may eventually be obtained.

Conodonts of the Silurian and Lower Devonian are only little known as yet. There seem to have been only a few new and characteristic forms developed during this time (*e.g. Polygnathoides*). Stratigraphic subdivision may be possible according to the range of certain species. In the uppermost Silurian (Ludlow) *Ctenognathus* (a long ranging blade) is the most common representative. In the Middle Devonian, species of *Polygnathus* (with a blade and a narrow basal cavity), and *Icriodus* (with a very wide basal cavity and three rows of node-like denticles) are characteristic. Both of these are platform types, a group which includes some of the better index fossils in younger formations.

The Upper Devonian is the time of the greatest development of conodonts in diversity as well as abundance. Descendents of *Polygnathus*, such as *Palmatolepis* (with azygous node) and *Ancyrodella*, have produced short-lived species useful for recognition of zones. Besides, there are also present many long ranging partial-genera, such as *Ellisonia* (with bilateral symmetry and median branch, but no basal cavity),

Hindeodella (a long bar), *Neoprioniodus* (with a large main cusp on one end), and *Ligonodina*. In the late Upper Devonian occur the first representatives of Gnathodontidae (with a long blade and a wide basal cavity).

The Lower Mississippian is characterized by *Siphonodella* (similar to *Polygnathus*, but with 2–6 ridges besides the blade), and *Pseudopolygnathus*. In the Upper Mississippian *Gnathodus* is common. Descendents of this genus, such as *Streptognathodus*, are the predominant forms in the Pennsylvanian. In the Upper Pennsylvanian, *Gondolella* (a platform which has been developed out of a bar type) has produced characteristic species, mostly with ridges on the plate.

Conodonts of the Permian and Triassic are still only little known. *Gondolella* is represented for the most part by species having a smooth plate. Representatives of the Gnathodontidae seem also to be present. In the Triassic many of the long ranging partial-genera, such as *Neoprioniodus*, *Ellisonia* and *Ctenognathus* are present. Species of *Gondolella* seem to be valuable as index fossils. In Middle Triassic strata a reduction in number of disjunct genera can be noted.

ADVANTAGES OF CONODONTS IN STRATIGRAPHY

To date, conodonts have been found in marine sediments from early Upper Cambrian to Middle Triassic in age. Their possibilities for application in biochronology and stratigraphy are based on: time sensitivity, common occurrence, characteristic morphology, stable evolutionary trends, wide geographic distribution, resistance against mechanical wear, and insolubility in certain acids. Their insolubility is particularly useful and offers wide possibilities for practical application. Conversely the extreme durability causes some difficulties in interpretation of the data found in field and laboratory.

Chemical composition.—Conodonts are composed of a calcium carbonate-apatite and are resistant to acetic acid CH_3COOH, monochloride-acetic acid $CH_2ClCOOH$, and formic acid HCO_2H. Therefore the fossils can be recovered from limestone by digestion of the matrix. In this way it is possible to secure excellently preserved conodont material. In cases where the limestones are somewhat metamorphosed and other fossils destroyed, conodonts may still be preserved sufficiently for comparison. Chitinozoa and Hystrichophaeriidae can be prepared with the same techniques.

Ecologic variability.—Due to their chemical composition, conodonts can be found in euxinic sediments, which are deposited under an exclusion of oxygen. With the exception of horny brachiopods, hardly any other fossils are preserved in this environment. An example of this type of rock is black shale, widely distributed in the Eastern Interior and Midwestern part of the United States.

Resistance to mechanical abrasion.—Distinctive gross features of some genera and species make it possible to determine fragments, secured by mere crushing of sandstone or quartzite samples.

Size.—As foraminifers and ostracodes, conodonts may be secured from random surface collections or well samples.

Ubiquitous occurrence.—In many Paleozoic formations conodonts are more widely distributed and more common than ostracodes, arenaceous foraminifera, small horny brachiopods, chitinozoa, scolecodonts, fish-teeth and scales, holothurian sclerites, and other microfossils.

Determinative features.—Conodonts may be determined from external features, without further preparation. For stratigraphic work, preparation of thin sections is unnecessary. The histology is, with the possible exception of Neurodontiformes, essentially the same in all conodonts (Gross, 1954, p. 79).

Time sensitivity.—Particularly in the Ordovician, Upper Devonian, Lower Mississippian, and probably Lower and Middle Triassic, considerable time sensitivity of species (and to some extent genera) has been observed. Eventually it may be applied for establishing of zones and subzones. In the early Upper Devonian a number of species seem to be better index fossils than even the ammonoids.

Independence of lithofacies.—Distribution of conodonts do not appear to depend on facies factors to any large extent. They are excellent tools for correlation in various types of facies.

Geographic range.—Closely similar conodont faunas are widely distributed. Identical species have been found in three different

continents (Pl. 145, fig. 1–4,12–20). Therefore, they may be regarded as one of the best fossils for long range correlation.

LIMITATIONS OF CONODONTS IN STRATIGRAPHY

Disjunct elements.—Conodonts are disjunct parts of a still unknown animal. The study of natural assemblages has demonstrated that in a single animal there may be present up to 5 partial-genera and 22 elements (Rhodes, 1954, p. 449). The number of forms which are present in any sample therefore is much larger than the number of "natural" species. Stratigraphically, this large number of "species" represents a difficulty. At least in the early stages of investigation it seems advisable to concentrate the study on a few important partial-genera and to work out carefully the differences between species.

Stage of knowledge.—Conodonts of many formations are not yet studied sufficiently to be used as index fossils. Establishment of more precise diagnoses for species and genera may be attained by increasing the number of morphological features used in descriptions and comparisons. Eventually, it will lead to a better understanding of even those forms now regarded as long ranging.

Improved techniques for preparation make it possible to secure more and better preserved material than previously. This also may lead to an increased knowledge of the forms.

Variability.—In many cases there is a considerable degree of intraspecific variation. This fact produces some difficulties in determination of conodonts. Even a thorough knowledge of the holotype may not be sufficient to recognize atypical specimens belonging to the same species. Additional figures of paratypes as well as description of variants seems to be desirable to define the range of variability within a species.

Stereophotography in single cases may be a valuable technique to demonstrate critical features. However, other things equal, the space required for one pair of stereophotographs would allow about 3 times as many single pictures. In my opinion, additional illustrations of different views or specimens are more valuable.

Limited visibility.—As most microfossils, conodonts are usually invisible in the rock with the unaided eye or with a simple lens. This is particularly true for conodonts preserved in limestone or unbedded shale, where in many cases they are invisible even with a binocular microscope and 20× enlargement. Although a few specimens may be discovered in the field, proper examination for conodonts can be done only by washing samples in a laboratory. As a rule, conodonts constitute only a very small volume of the rock, and it is necessary to utilize a relatively large amount of material.

The chances of securing good material can be increased by selection of only certain layers in a section which seem to be best suited for this purpose. Working through a section layer by layer will produce the same results, but requires much more time and material.

Mixed faunas.—Secondary deposition of conodonts mixed with younger forms or as displaced ("ghost") faunas is often reported (Branson & Mehl, 1941; Ellison, 1946; Hass, 1953, etc.). This complication may be due to the shape and to resistance against mechanical wear. Naturally, fossils in secondary deposits may be a source of error, if applied in stratigraphy. Therefore, interpretation and stratigraphic evaluation of the conodont zones seems to be necessary.

Mixed faunas are often recognized on differences in color, preservation or luster. In some cases these differences may be made more distinct by observation in ultraviolet light. Differences in abrasion also may indicate the possibility of mixing. However, I have seen cases where no differences in preservation are recognizable, and where all the various distinguishing techniques fail to work.

The safest method for recognition of mixed faunas can only be achieved by knowledge of the older types as well as the geological situation at the locality. For example, several samples of the Upper Devonian Grassy Creek shale in Missouri have yielded conodonts of Maquoketa (Upper Ordovician) age. This circumstance is not particularly surprising, because the Grassy Creek shale in Missouri overlies the conodont-rich Ordovician disconformably. However, conodonts of Ordovician and Upper Devonian age are readily distinguishable, and therefore the evaluation of findings in this case is not difficult.

If the time interval between mixed faunas is short, recognition involves an accurate knowledge of the normal associations. This may be attained only by studying other localities with sediments of the same age. It is very improbable that contamination in distant localities will be the same, therefore uniformity may be concluded to indicate uncontaminated material. To make possible comparisons of this kind, accumulation of detailed stratigraphic records on the occurrence of the different species and genera is desirable.

"Ghost" faunas, as a rule, have been derived from different horizons and may therefore be recognized in the same fashion. In order to facilitate comparisons, charts which give a detailed account of the composition of an association in a certain horizon, are particularly valuable. Excellent examples have been published by Ellison, 1941, Hass, 1953, Lindström, 1954, etc. Many of the considerations given above may be also true for other microfossils (pollen, hystrichosphaerids) which are resistant to abrasion and solution.

REFERENCES

BECKMANN, H., 1953, Die Bedeutung von conodonten für die stratigraphie des Devons in der Lahn- und Dillmulde: Notizbl. hess. L.-Amt Bodenforschung, vol. 81, p. 63–68, pl. 2.

BRANSON, E. B., & MEHL, M. G., 1933–1934, Conodont studies no. 1–4: Univ. Missouri Stud. vol. 8, 349 p., 28 pl.

——, & ——, 1934, Notes on the ecology of the conodonts (abstract): Geol. Soc. Amer., Proc. 1933, p. 362.

——, & ——, 1941, The recognition and interpretation of mixed conodont faunas: Denison Univ. Bull., vol. 40, no. 14, Jour. Sci. Lab., vol. 35, p. 195–209.

——, & ——, 1944, Conodonts; *in* Index fossils of North America, by Shimer, H. W., & Shrock, R. R., p. 235–246, pl. 93–94.

——, & ——, 1948, Conodont homonyms and names to replace them: Jour. Paleont., vol. 22, p. 527–528.

COOPER, C. L., 1945, Conodont assemblage from the lower Kinderhook black shales (abstract): Geol. Soc. Amer., Bull., vol. 56, p. 1153.

DECKER, C. E., & MERRITT, C. A., 1928, Physical characteristics of the Arbuckle limestone: Oklahoma Geol. Surv., circular no. 15, 55 p., 5 pl.

DU BOIS, E. P., 1943, Evidence on the nature of conodonts: Jour. Paleont., vol. 17, p. 155–159, pl. 25.

ELLISON, S. P., 1941, Revision of the Pennsylvanian conodonts: Jour. Paleont., vol. 15, p. 107–143, pl. 20–23.

——, 1944, Ecology of conodonts: Natl. Research Council, Div. Geology & Geography, App. K, Ann. Rept. 1943–1944, p. 3–5.

——, 1946, Conodonts as Paleozoic guide fossils: Amer. Assoc. Petrol. Geol., Bull., vol. 30, p. 93–110.

FAY, R. O., 1952, Catalogue of conodonts: Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, 206 p.

FRIZZELL, D. L., & EXLINE, H., 1955, Monograph of fossil holothurian sclerites: Univ. Mo., School of Mines & Metallurgy, Bull., tech. ser., no. 89, 204 p., 11 pl.

FURNISH, W. M., 1938, Conodonts from the Prairie du Chien (Lower Ordovician) beds of the Upper Mississippi Valley: Jour Paleont., vol. 12, p. 318–340, pl. 41–42.

GROSS, W., 1954, Zur Conodonten-Frage: Senckenbergiana lethaea, vol. 35, p. 73–85, pl. 1–5.

GUNNEL, F. H., 1931, Conodonts from the Fort Scott limestone of Missouri: Jour. Paleont., vol. 5, p. 244–252, pl. 29.

HARLEY, J., 1861, On the Ludlow bone-bed and its crustacean remains: Quar. Jour. Geol. Soc., London, vol. 17, p. 542–552, pl. 17.

HASS, W. H., 1941, Morphology of conodonts: Jour. Paleont., vol. 15, p. 71–81, pl. 12–16.

——, 1953, Conodonts of the Barnett formation of Texas: U. S. Geol. Surv. Prof. Paper 243–F, p. 69–94, pl. 14–16.

HOWELL, B. F., et al., 1944, Correlation of the Cambrian formations of North America: Geol. Soc. Amer., Bull., vol. 55, p. 993–1003.

HUDDLE, J. W., 1934, Conodonts from the New Albany shale of Indiana: Bull. Amer. Paleont., vol. 21, no. 72, p. 1–136, pl. 1–12.

LANGE, F. W., 1949, Polychaete annelids from the Devonian of Paraná, Brazil: Bull. Amer. Paleont., vol. 33, no. 134, p. 5–104, pl. 1–16.

LINDSTRÖM, M., 1954, Conodonts from the lowermost Ordovician strata of south-central Sweden: Geol. Fören. Förhandl., vol. 76, p. 517–604, pl. 1–10.

MILLER, A. K., & YOUNGQUIST, W. L., 1947, Conodonts from the type section of the Sweetland Creek shale in Iowa: Jour. Paleont., vol. 21, p. 501–517, pl. 72–75.

MÜLLER, K. J., 1956, Zur Kenntnis der Conodontenfauna des Oberdevons in Europa. 1. Die Gattung Palmatolepis: Abhandl. Senckenbergische Naturforschende Gesellschaft, in press.

——, 1956, Triassic conodonts from Nevada: Jour. Paleont., vol. 30, p. 818–830, pl. 95,96.

PANDER, C. H., 1856, Monographie der fossilen Fische des silurischen systems der russisch-baltischen Gouvernements: St. Petersburg, 91 p., 8 pl.

RHODES, F. H. T., 1952, A classification of Pennsylvanian conodont assemblages: Jour. Paleont., vol. 26, p. 886–901, pl. 126–129.

——, 1953a, Nomenclature of conodont assemblages: Jour. Paleont., vol. 27, p. 610–612.

——, 1953b, Some British Lower Paleozoic conodont faunas: Royal Soc. London, Philos. Trans. Ser. B, no. 647, vol. 237, p. 261–334, pl. 20–23.

——, 1954, The zoological affinities of the conodonts: Biological Reviews, vol. 29, p. 419–452.

RICHTER, R., 1948, Einführung in die Zoologische Nomenklatur durch Erlauterung der Internationalen Regeln: Senckenbergische Natur-

forschende Gesellschaft, Buch 15, 252 p., Frankfurt a. Main.

RUEDEMANN, R., 1934, Paleozoic plankton of North America: Geol. Soc. Amer., Mem. 2, 141 p., 26 pl.

SANNEMANN, D., 1955, Oberdevonische Conodonten (to IIα): Senckenbergiana lethaea, vol. 36, p. 123–156, pl. 1–6.

SCHMIDT, H., 1934, Conodonten-Funde in ursprünglichem Zusammenhang: Paläont. Zeitschr., vol. 16, p. 76–85, pl. 6.

——, 1950, Nachträge zur Deutung der Conodonten: Decheniana, vol. 104, pl. 11–19.

SCOTT, H. W., 1934, The zoological relationship of the conodonts: Jour. Paleont., vol. 8, p. 448–455, pl. 58–59.

——, 1942, Conodont assemblages from the Heath formation, Montana: Jour. Paleont., vol. 16, p. 293–300, pl. 37–40.

SHIMER, H. W., & SHROCK, R. R., 1944, Index fossils of North America: New York & London, 837 p., 303 pl.

STAUFFER, C. R., & PLUMMER, H. J., 1932, Texas Pennsylvanian conodonts and their stratigraphic relations: Univ. Tex. Bull. 3201, Contr. to Geol., 1932, p. 13–50, pl. 1–4.

STEWART, G. A., & SWEET, W. C., 1956, Conodonts from the Middle Devonian bone beds of central and west-central Ohio: Jour. Paleont., vol. 30, p. 261–273, pl. 33–34.

SYLVESTER-BRADLEY, P. C., 1954, Form-genera in paleontology: Jour. Paleont., vol. 28, p. 333–336.

THOMAS, L. A., 1949, Devonian-Mississippian formations of southeast Iowa: Geol. Soc. Amer., Bull., vol. 60, p. 403–437, pl. 1–4.

TRUSHEIM, F., 1937, Triopsiden (Crust. Phyll.) aus dem Keuper Frankens: Paläont. Zeitschr., vol. 19, p. 198–216, pl. 13–14.

ULRICH, E. O., & BASSLER, R. S., 1926, A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species: U. S. Nat. Mus. Proc., vol. 68, art, 12, p. 1–63, pl. 1–11.

VOLBORTH, A. v., 1861, Vorkommen von Conodonten in England und Schweden: N. Jb. f. Mineralogie, Geognosie, Geologie, etc. p. 464–465.

WELLER, J. M., 1949, Paleontologic classification: Jour. Paleont., vol. 23, p. 680–690.

YOUNGQUIST, W. L., 1952, Triassic conodonts from southeastern Idaho: Jour. Paleont., vol. 26, p. 650–655.

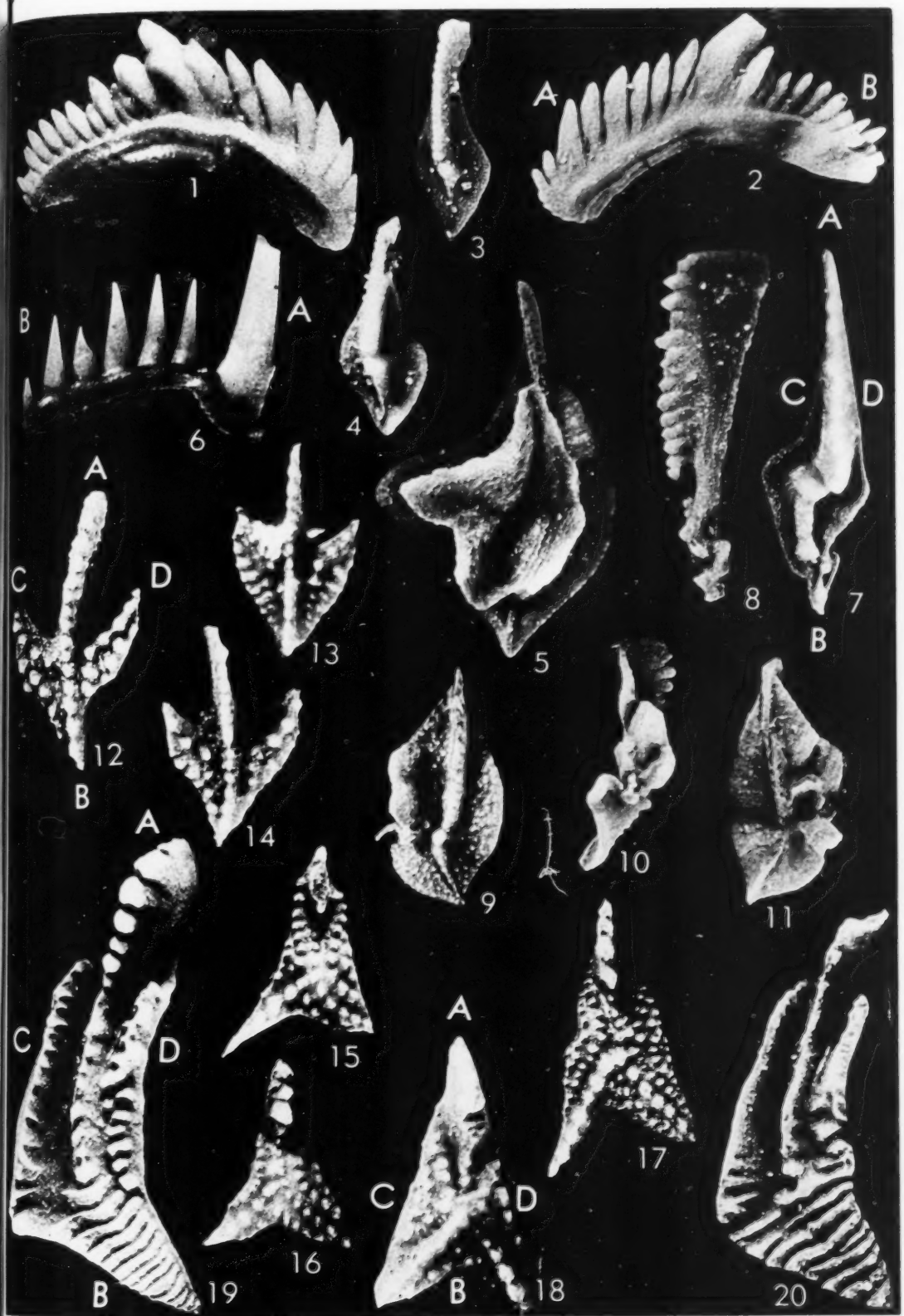
——, & PETERSON, R. F., 1947, Conodonts from the Sheffield formation of north-central Iowa: Jour. Paleont., vol. 21, p. 242–253, pl. 36–38.

EXPLANATION OF PLATE 145

All figures are unretouched photographs, ×40. Specimens SUI = State University of Iowa, SMF = Senckenberg Museum Frankfurt a. Main, and UWA = University of Western Australia. *2,6,7,12,18, 19*, the letters A, B, C, D designate the orientation.

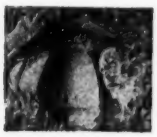
FIG. *1–4,12–20*—Examples of the great similarity between specimens from different continents. *1,2, Bryantodus* sp. *1*, from an early Upper Devonian (with *Manticoceras*) shale at Amana, Iowa Co., Iowa. SUI 8077. *2*, from the *Manticoceras* limestone Fitzroy basin Western Australia. UWA 37038. Present differences between both forms possibly can be regarded as interspecific variation. *3,4, Palmatolepis* (*Deflectolepis*) *minuta* (Branson & Mehl, 1934). *3*, from the *Platyclymenia*-Stufe, Schleiz, Thuringia, Germany. SMF XVI 258. *4*, from the *Sporadoceras* limestone with *Platyclymenia*, Fitzroy basin, Western Australia. UWA 37039. This species has been originally described from the Grassy Creek shale in Missouri. *12–14, Ancyrodella* sp. *12*, from Bredelar near Madfeld, Germany. SUI 8078. *13*, from Amana, Iowa Co., Iowa. SUI 8079. *14*, from Fitzroy basin, Western Australia. UWA 37040. These specimens have been found associated with *Manticoceras*, an index fossil of the early Upper Devonian. *15–18, Ancyroides* aff. *A. uddeni* Miller & Youngquist. *15,16*, two specimens from a shale near Amana, Iowa Co., Iowa, for demonstration of the range of variability within a horizon. SUI 8080. *17*, from the "Kellwasserkalk" at Braunau near Wildungen, Kellerwald, Germany. SUI 8082. *18*, from the *Manticoceras* limestone Fitzroy basin in Western Australia. UWA 37041. All four specimens have been found associated with *Manticoceras*. In Europe the genus *Ancyroides* seems to be confined to the upper part of the *Manticoceras*-Stufe. *19,20, Polygnathus linguiformis* Hinde. *19*, from the Genundewa (Conodont-limestone) at Wanakah, Erie Co., New York. SUI 8083. *20*, from the Odershauser Kalk, Odershausen, Kellerwald, Germany. SUI 8084. The similarity of both forms is striking, the latter may be regarded only as belonging to another subspecies.

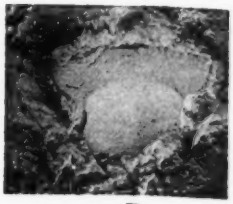
FIG. *5–11*—Examples of structure of the base, regeneration, heeling of fractures, and monstrosity. *5, Palmatolepis* (*Manticolepis*) *subrecta* (Miller & Youngquist). Lower side of sinistral specimen with preserved base, and visible growth lines. From an early Upper Devonian shale at Amana, Iowa Co., Iowa. SUI 8074. *6, Neoprioniodus* sp. The third denticle from B is broken off and has been regenerated. The same is true probably with the main cusp. From an early Upper Devonian shale at Amana, Iowa Co., Iowa. SUI 8075. *7,8, Palmatolepis* (*Deflectolepis*) *minuta* (Branson & Mehl), *7*, upper, *8*, lateral (from D) view of gerontic, dextral specimen. The tip of the plate is broken off and heeled on again in somewhat changed position. *Cheiloceras* or *Platyclymenia*-Stufe of the Upper Devonian, Öttersdorf near Schleiz, Thuringia, Germany. SMF XVI 257. *9–11, Palmatolepis* (*Manticolepis*) *subrecta* (Miller & Youngquist), *9*, upper, *10*, lateral (from C) and *11*, lower view of dextral specimen. Monstrosity which is probably caused by damage in an early growth stage. From an early Upper Devonian shale at North Liberty, Johnson Co., Iowa. SUI 8076.


1
2
A
B
3
4
5
6
A
B
7
8
C
D
9
10
11
12
13
14
15
16
17
18
19
20

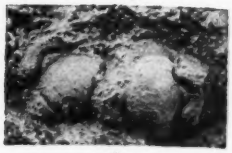
1

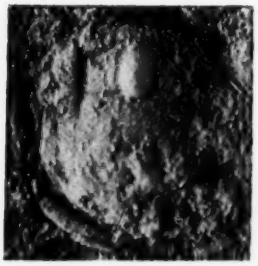
2


3


5

4


6

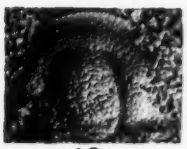

7

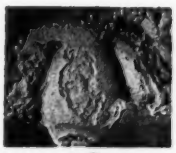
8

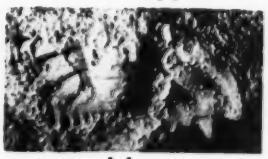
9

11

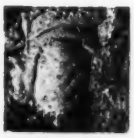
12


13

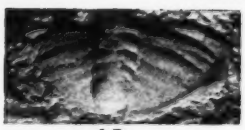

10


14

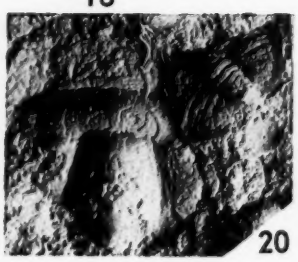
16


17

18


19

15


20

21

22

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1341–1349, PL. 146, NOVEMBER 1956

REVISIONS IN NOMENCLATURE AND NEW SPECIES OF CAMBRO-ORDOVICIAN TRILOBITES FROM THE MARATHON UPLIFT, WEST TEXAS

JAMES LEE WILSON
Shell Development Company, Houston

ABSTRACT—Recent revisions of trilobite nomenclature and helpful correspondence from specialists studying Late Cambrian and Lower Ordovician faunas have made possible improved nomenclature for the trilobites described from the Marathon uplift by the writer in 1954. A total of twenty-three species are discussed, a few new forms described and figured from the Woods Hollow exotic boulders, and the small fragmentary fauna from the Dagger Flat formation of the Marathon in situ section is illustrated. Re-study of the trilobites described from the "*Parabolinella*" limestone of the Canadian Rocky Mountain trench area by Kobayashi results in the naming of a new genus *Olenaspella* to receive *Parabolinella evansi* Kobayashi and *P. occidentalis* Wilson. Importance of the Marathon faunas in international correlation is reviewed with no significant changes in the correlations proposed by the writer in 1954.

INTRODUCTION

IN 1954 the writer published descriptions of Cambrian and Lower Ordovician trilobites found in exotic boulders in the Middle Ordovician Woods Hollow shale and of several Lower Ordovician forms discovered in the Marathon and Dagger Flat formations, the oldest beds of the graptolitic facies exposed in the Marathon folded belt. Since this time, helpful taxonomic criticism has been received from persons interested in faunas closely related to these from Europe, South America, Vermont, and the western Cordillera of North America. In addition, studies in connection with the trilobite section of the Treatise on Invertebrate Paleontology have made apparent errors in nomenclature which should be corrected because the faunal lists from these boulders are of importance in world-wide correlation.

EXPLANATION OF PLATE 146

FIG. *1,2*—*Armonia* = *Modocia* sp. undet. but like those in Park shale of Montana, *1*, cranidium, ×5, and *2*, pygidium, ×5 from Woods Hollow exotic boulder 1955 BM-10, Marathon uplift.

3—*Aphelaspis* sp. undet., cranidium, CW-350, ×2½, from Woods Hollow exotic boulder BM-4, Marathon uplift.

4,5,6—*Richardsonella* sp. undet. *4,6*, dorsal views, ×5, of fragmentary cranidia, *5*, dorsal view, ×6, of anterior part of fragmentary cranidium, all from small Woods Hollow exotic boulder 1955 BM-9, Marathon uplift.

7—*Pseudagnostus* sp. undet., pygidium, ×13, from coll. 1, section 4 miles southwest of Marathon, lowest bed in measured section, Dagger Flat formation, 225 feet below top.

8—*Bolaspidella macgerriglei* (Raymond), crandium, ×6, from Woods Hollow exotic boulder 1955 BM-10, Marathon uplift.

9—*Aphelaspis* sp. undet. cranidium, ×2, from Fish Drilling Co. no. 1 Postell, depth 5044–45, correlated with Lion Mountain formation, Kinney County, Texas.

10—*Aphelaspis* sp. undet., fragmentary cranidium, ×2, from Fish Drilling Co., no. 1 Postell, depth 5039-40 correlated with Lion Mountain formation, Kinney County, Texas.

11—*Geragnostus rudis* Salter, pygidium, ×13, from coll. 1, section 4 miles southwest of Marathon, lowest bed in measured section, Dagger Flat formation, 225 feet below top.

12—*Litagnostus*, pygidium, ×13, from coll. 1, section 4 miles southwest of Marathon, lowest bed in measured section, Dagger Flat formation, 225 feet below top.

13—*Dytremacephalus* cf. *D. laevis* Palmer, cranidium, ×2½, 10 feet below top of Bolsa quartzite, Blue Mountain, Chiricahua-Dos Cabezas area, southeastern Arizona; collected by F. Sabins.

(*Explanation of Plate 146 continued on next page*)

The following paragraphs not only bring up to date nomenclature of certain previously described species, but also comment on their significance in intercontinental correlation and geosynclinal facies position. Additional species from other boulders and from the Dagger Flat formation are also described. In the course of discussion of faunas from Woods Hollow boulder BM-4, Kobayashi's specimens from the "*Parabolinella*" *evansi* fauna of western Canada are discussed and re-illustrated.

DRESBACHIAN FORMS IN WILSON'S 1954 PAPER

NASOCEPHALUS NASUTUS Wilson

As pointed out in addendum and footnote (Wilson, 1954, p. 249,268) the species *Agraulos anceps* Westergard, *A. difformis* (Angelin), *A. aculeatus* (Angelin), and *A. acuminatus* (Angelin) (Westergård, 1953, p. 4–6, pl. 1, fig. 1–17, pl. 2, fig. 1–3) are closely similar to *Nasocephalus flabellatus* and *N. nasutus*. *Nasocephalus* species differ from the former in having a slightly less quadrate glabella, narrower, more elevated fixed cheeks, and possibly smaller eyes. The writer believes that insufficient material exists of *Nasocephalus* to permit its assignment to *Agraulos* or the assignment of the species described by Westergård to *Nasocephalus*. Nevertheless strong similarity between the forms suggests correlation of the Atlantic province zone of *Solenopleura brachymetopa* with the *Cedaria* fauna containing *Nasocephalus* in the Woods Hollow boulders. *Agraulos difformis* and *A. acuminatus* (= *Nasocephalus flabellatus?* and *N. nasutus* Wilson?) are reported associated with very late *Paradoxides*, *Centropleura*, fauna on Bennett Island, Arctic Sea by Kobayashi (1943, p. 283) and Westergård (1953, p. 6). This correlation is further emphasized by Shaw (personal communication) and Howell & Duncan (1939, p. 2) who state that in Vermont the *Centropleura vermontensis* fauna contains some genera which are found in the *Paradoxides forchhammeri* zone and other forms found in the *Cedaria* zone. Howell & Duncan consider the Vermont fauna youngest Middle Cambrian (therefore at the stratigraphic position of the *Solenpleura brachymetopa* fauna of Sweden where the highest *P. forchhammeri* occurs). The writer suggests that the *Centropleura* fauna might represent a biofacies equivalent to the *Cedaria* fauna of the western Cordilleran and mid-continent regions.

EXPLANATION OF PLATE 146 (*continued*)

14—*Ctenopyge?* spinose olenid-type pygidium, very small and possibly immature form, pygidium, ×6½, from coll. 1, section 4 miles southwest of Marathon, lowest bed in measured section Dagger Flat formation, 225 feet below top.

15—*Ctenopyge?*, clay mould of fragmentary cranidium, ×13, from coll. 1, section 4 miles southwest of Marathon, lowest bed in measured section, Dagger Flat formation, 225 feet below top.

16—"*Taenicephalus*" *megalops* Kobayashi 1938 (pl. 16, fig. 8a), deformed cranidium, ×3, C. G. S. Mus. no. 12002, from Kobayashi's loc. P 6/8 west of Harrogate, B. C.

17—"*Taenicephalus*" *megalops* Kobayshi 1938 (pl. 16, fig. 35) deformed cranidium, probably olenid, picture reversed, ×2½, C. G. S. Mus. no. 12003, from Kobayashi's loc. P 6/8, west of Harrogate, B. C.

18—"*Taenicephalus*" *longifrons* Kobaysahi 1938 (pl. 16, fig. 25) probably an olenid species with unusually long brim, small cranidium, ×2½, C. G. S. Mus. no. 11940, from Kobayashi's loc. P 6/6, west of Harrogate, B. C.

19—"*Taenicephalus*" *longifrons* Kobayashi 1938 (pl. 16, fig. 26), pygidium, ×3, C. G. S. Mus. no. 11941, from Kobayashi's loc. P 6/6, west of Harrogate, B. C.

20—*Olenapsella evansi* (Kobayashi) = *Parabolinella evansi*, cranidium, ×3, not figured by Kobayashi showing limestone preservation and pygidium assigned to "*Taenicephalus*" *longifrons* by Kobayashi on piece of rock bearing C. G. S. Mus. no. 11941, from Kobayashi's loc. P 6/6, west of Harrogate, B. C.

21—*Olenaspella evansi* (Kobayashi) = *Parabolinella evansi* Kobayashi 1938 (pl. 16, fig. 11), lectotype cranidium, ×3, exfoliated specimen flattened in shaly limestone, C. G. S. Mus. no. 11958, from Kobayashi's loc. P 6/5, west of Harrogate, B. C.

22—*Dunderbergia canadensis* Kobayashi 1938 (pl. 16, fig. 16), mature and immature cranidia, syntypes, with *Homagnostus acutus* pygidium, ×2½, C. G. S. Mus. nos. 11954 and 11955 respectively, Kobayashi's loc. P 6/5, west of Harrogate, B. C.

BLOUNTIA cf. B. ASSIMILIS Resser

This *Blountia* species which is also associated with *Cedaria* cf. *C. gaspensis* and *Nasocephalus nasutus* in Woods Hollow boulder SS-33 has recently been found with *Bolaspidella macgerriglei* in boulder 1955 BM-10. The species belongs to a group containing broad borders and arcuate frontal areas. It is closest to *B. assimilis* Resser, *B. mimula* Walcott, and *B. gaspensis* Rasetti. The common *Blountia* species from the Nolichucky shale and Levis Dresbachian boulders resemble the species from the Dresbachian Woods Hollow boulders more than do the species of the genus from the Montana and Wyoming Rockies.

ARMONIA sp. undet.
Pl. 146, fig. 1,2

This cranidium and pygidium is found with *Bolaspidella macgerriglei* in boulder 1955 BM-10. The cranidium is closest to those found with *Bolaspidella* species in the Park shale fauna of Montana which is of latest Medial Cambrian age. In recent years generally such cranidia have been assigned to *Modocia* Resser 1935 but the genus is probably a junior synonym of *Armonia* Walcott 1924 (Lochman-Balk, personal communication). The Park shale fauna has been described in a thesis manuscript by Norman Denson but never published. The cranidium is similar to those of *Armonia* and *Modocia* illustrated by Lochman & Duncan (1944, pl. 11, fig. 35–43, pl. 16, fig. 29–37) except for the narrower fixed cheeks and well-developed ocular ridges. The short pygidium illustrated is associated with this type of cranidium in the Park shale collections of Denson and is identical to those assigned to *Modocia* by Palmer (1954, p. 762, 763) from collections of oldest Dresbachian age in Texas.

BOLASPIDELLA MACGERRIGLEI (Raymond)
Pl. 146, fig. 8

Hysteropleura macgerriglei RAYMOND, 1937, Geol. Soc. Amer. Bull., vol. 48, p. 1094, pl. 1, fig. 22.

Bolaspidella macgerriglei SHAW, 1952, Jour. Paleont., vol. 26, no. 3, p. 478, pl. 57, fig. 44.

The specimen is small (4 mm. long). Its features are typically those of *Bolaspidella* as outlined by Shaw (1952, p. 477) and Palmer (1954, p. 739). The upturned, thickened border was destroyed in preparation. The palpebral lobes of the species are apparently located more posteriorly than on many *Bolaspidella* species and on this specimen were probably almost at the midpoint of the glabella. Such forms occur in the Park shale fauna of Montana. Species described by Palmer (1954, p. 740,741) from the Llano Uplift Dresbachian have more anteriorly located eyes. A single cranidium is present in boulder 1955 BM-10.

OLENID FAUNAS

"PARABOLINELLA" INCERTA (Rasetti)
= OLENUS sp. undet.

Dr. G. Henningsmoen, Paleontological Museum, Oslo, Norway informs the writer that recent studies of the olenids have made it advisable to restrict the genus *Parabolinella* to forms more closely related to the genotype, *P. limitis* Brogger and that true *Parabolinella* is not found below the Tremadocian. Henningsmoen considers the writer's American olenids of the *Parabolinella incerta* type a new species of *Olenus* sensu stricto. The fragmentary material representing the Woods Hollow boulder species makes a positive identification with *Olenus* s.s. impossible at this time. However, such an identification would make the faunal associations in boulders SS-26, BM-2 and BM-4 accord better.

It is important to emphasize the correlation difficulty manifest by the writer's earlier assignment of the olenid species in boulders SS-26, SS-27, BM-new, and BM-2 to "*Parabolinella*" *incerta*. The faunas of these boulders are connected only by the occurrence of this species. BM-2 contains a typical BM-4 boulder fauna and therefore must be correlated with the late *Aphelaspis* zone of North America (Wilson, 1954, p. 261). But *P. incerta* Rasetti is associated with younger trilobites of the Late Cambrian (no older than Late Franconian) where first described in the Levis boulders. It is conceivable that in the geosynclines surrounding the North American craton, olenids evolved slowly and identical or very closely related forms migrated at intervals toward the continental borders of the troughs and became mixed with remains of the more rapidly

evolving and varied shelf faunas at different geologic times.

HIGHER APHELASPIS ZONE FORMS FROM BOULDER BM-4

"PARABOLINELLA" EVANSI Kobayashi = OLENASPELLA EVANSI (Kobayashi)

Pl. 146, fig. 20,21

Types of this species described by Kobayashi (1938, p. 186) from the Rocky Mountain Trench area in southern British Columbia have been studied and compared with the material described as *Parabolinella evansi* by the writer from boulder BM-4 in the Woods Hollow shale. As indicated previously (Wilson, 1954, p. 263) these specimens differ from typical olenids in having large palpebral lobes and thick anterior borders. The writer has profited from advice by Dr. G. Henningsmoen of the Norwegian Paleontological Museum, Oslo, and Dr. Christina Lochman-Balk, New Mexico Bureau of Mines and Mineral Resources, who have also pointed out these differences. A new genus *Olenaspella* is proposed for the species *Parabolinella evansi* and is made to include also *P. occidentalis.*

Genus OLENASPELLA Wilson, n. gen.

Cranidium of moderate size (large specimen more than 15 mm. broad at base), slightly convex. Glabella convex, slightly longer than wide at base, essentially untapered but rounded frontally, in profile horizontal except for slight anterior deflection; three pairs of glabellar furrows, anterior pair short and faint, posterior two pairs well-defined, oblique and characteristically slightly sigmoid; occipital furrow and ring normal; dorsal furrow well-defined. Brim only moderately deflexed anteriorly and laterally, wide (see table of measurements, Wilson, 1954, p. 281); marginal furrow and border well-defined, the latter well-developed and thickened gradually toward axis. Fixed cheeks almost horizontal, slightly downsloping laterally, width about half that of base of glabella on type species but narrower on *Olenaspella occidentalis;* ocular ridges strong and palpebral lobes large, centered on glabella; posterior limb narrower than on typical olenids.

Free cheek slightly convex with well-developed border which is extended into a well-tapered genal spine.

Facial suture intramarginal anteriorly halfway to center, directed inward slightly behind anterolateral corner and posterior to large eye directed rather straight outward.

Brim on cranidium and ocular platform of free cheek ornamented by well-defined anastomosing ridges.

Pygidium illustrated by Kobayashi (1936, pl. 15, fig. 10) and by writer (1954, pl. 25, fig. 16) possesses well-defined convex axis with four strong rings and a blunt posterior end reaching almost to border, pleural lobes well-segmented, each segment showing faint pleural furrows. Six spines are present on the border in Kobayashi's original figure although he states that only four may be counted (1936, p. 93, pl. 15, fig. 10). A smaller pygidium associated with the cranidium illustrated by Kobayashi in 1938 (pl. 16, fig. 11) shows only four spines as does the large pygidium from Woods Hollow boulder BM-4 (Wilson, 1954, pl. 25, fig. 16). A collection of topotype material made by the writer in 1956 shows numerous large pygidia all with four spines.

The above mentioned material was collected from Evans' original locality on Jubilee Mountain in a structurally isolated outcrop which unfortunately adds nothing to knowledge of stratigraphic position of the fauna. It is, however, large enough to assure correct association of parts of *Olenaspella,* to get some idea of size variation of type species, and to obtain information on associated forms. The material will be studied and described at a later date.

Type species: *Olenaspella evansi = Parabolinella evansi* Kobayashi 1936. Kobayashi in 1936 gave excellent and complete illustrations but failed to designate types and in 1938 illustrated a more complete cranidium, C. G. S. Mus. no. 11958 (pl. 16, fig. 11) which the writer has studied and considers the type.

Discussion.—The writer has described the material from boulder BM-4 in some detail (1954, p. 281,282). After comparison of this material with the types of *"Parabolinella" evansi* it is still apparent that what slight differences occur between the two samples can be attributed to flattening of the Canadian material. The following dis-

tinctions from typical olenids given by the writer (1954, p. 281) for the species serve for the genus: (1) comparatively thick and arcuate border, (2) medially located large thick palpebral lobes and thick ocular ridges, (3) narrower posterior limb than on other olenids, (4) axially long frontal area, (5) a large cylindrical glabella. The two well-defined oblique pairs of sigmoid furrows and anastomosing ornamentation ridges are also outstanding characteristics of the genus. The specific differences of *Olenaspella occidentalis* (Wilson) (*Parabolinella occidentalis* Wilson, 1951) from *Olenaspella evansi* have also been pointed out (Wilson, 1954, p. 282). Re-examination of topotype material of the Appalachian species shows that the only added differences are the less sigmoid character of the glabellar furrows and the slightly more posterior location of the anteriormost pair of glabellar furrows.

Geographic and structural distribution of genus.—Recent mapping of the Rocky Mountain trench area (Henderson, 1954 and North & Henderson, 1954, p. 15–81) indicates that the stratigraphically unplaced dark limestone bearing the *Olenaspella evansi* and *Dunderbergia* faunas lies in the complexly thrust faulted area bounding the western side of the Rocky Mountain trench, lying north of Jubilee Mountain and west of Harrogate Post Office, British Columbia. On the basis of field observations by Evans, Henderson, North, and the writer, it is impossible to obtain a measured section into which the dark limestone may be fitted. Dr. North (personal communication) informs the writer that these strata are of different lithic character from those of the main part of the Canadian Rockies front ranges. Notwithstanding, the strata do not belong structurally in the complexly folded, intruded, and faulted area of the Dogtooth-Purcell block west of the trench. The writer views them as a facies transitional between the eugeosynclinal and miogeosynclinal portion of the Rockies.

It appears probable that this species or one closely related occurs in the middle Gorge formation of Vermont whose fauna is described but unpublished by Miss Mary Gilman, Shell Oil Company, Casper, Wyoming. These specimens differ mainly in having slightly narrower fixed cheeks, and a more distal location of the genal spine on the free cheek. The associated fauna appears to be no older than Late Franconian to the writer.

Very close relations exist between the genus *Olenaspella* and the Australian genus *Eugonocare* (Whitehouse, 1939, p. 226,227, pl. 13, fig. 15–20, pl. 15, fig. 7b,10). Dr. Öpik states (personal communication to Dr. Lochman-Balk) that the cranidia are similar except that of *Eugonocare* is wider and that the "pygidia associated with *Eugonocare* are large and without spines, with a border, a terminal notch, five axial segments and five to six pleural ribs." Pygidia associated with *Olenaspella* in boulder BM-4 (Wilson, 1954, pl. 26, fig. 26,27) bear some resemblance to that of *Eugonocare* although a different and spinose type of pygidium is considered more probably to belong to *Olenaspella evansi*.

The exotic Woods Hollow boulder BM-4 which contains this same fauna represents part of a probable miogeosynclinal rock sequence which is now buried beneath the allochthonous strata of the Ouachita-Marathon folded belt which have been moved from farther south in the geosyncline.

In the Vermont lower Gorge formation the closely related species to *Olenaspella evansi* is also located in sediments on the edge of the interior part of the geosyncline.

The similar genus from Australia, *Eugonocare*, apparently lies far from the Tasmanian geosyncline and is the only occurrence of the form outside the margins of a geosynclinal trough.

COMPARISONS WITH KOBAYASHI'S SPECIMENS FROM THE "*Parabolinella* LIMESTONE" OF WESTERN CANADA

Immature form of OLENASPELLA or OLENUS

In examining the types of Kobayashi's "*Parabolinella*" *evansi* attention was directed to what had been described as an immature cranidium of this species (Kobayashi, 1938, pl. 16, fig. 14). Boulder BM-4 contains also an immature cranidium, probably of *Olenaspella evansi* (Wilson, 1954, pl. 25, fig. 15). This specimen is four times smaller than Kobayashi's but more resembles the holaspid form of the species. In the writer's opinion the form figured by

Kobayashi as an immature cranidium is a holaspid member of the typical olenids, probably *Olenus* s.s.

"TAENICEPHALUS" MEGALOPS Kobayashi

The writer stated (1954, p. 271) that the species described in 1938 by Kobayashi as *Taenicephalus megalops* (p. 183, pl. 16, fig. 7–10,35) from the black "*Parabolinella* limestone" in British Columbia and identified in boulder BM-4 of the Marathon region by the writer was very similar to forms in the upper Lion Mountain member of the Riley formation of the Texas Llano Uplift. Further study of the Texas faunas by Palmer (1954, p. 709–786) and comparison of Kobayashi's types with Lion Mountain specimens by the writer fails to indicate as close similarity as stated. The writer believes that the form described by himself as "*Taenicephalus*" *megalops* from boulder BM-4 (1954, pl. 26, fig. 28) despite the poor material is truly Kobayashi's species, but certainly not of the genus *Taenicephalus*. However, accurate identification of this form must await better material from both the Canadian and Texas localities. It is doubtful that this species is present in the Llano Uplift *Aphelaspis* zone of Texas.

The holotype cranidium of "*Taenicephalus*" *megalops* Kobayashi, 1938 (pl. 16, fig. 17) was not available for restudy. The remaining specimens are slightly deformed: C.G.S. Mus. no. 12002 (Kobayashi, 1938, pl. 16, fig. 8a), see Plate 146, figure 16, is probably synonymous with the holotype.

In the writer's opinion C.G.S. Mus. no. 12003 (Kobayashi, 1938, pl. 16, fig. 35), see Plate 146, figure 17, is probably a deformed olenid cranidium because of the flat fixed cheeks, thin anterior border and distinctive glabellar furrows.

"TAENICEPHALUS" LONGIFRONS Kobayashi
Pl. 146, fig. 18,19,20 (part)

The cranidium designated as type by Kobayashi (1938, pl. 16, fig. 25) for this species is to the writer's view, after examining the material, an olenid species possessed of an unusually axially long brim (see Plate 146, figure 18). Both the brim and fixed cheeks are much flatter than Kobayashi's illustration indicates; the heavy ocular ridges and general glabellar configuration resemble the features of an olenid. No cranidia of this type have been found in boulder BM-4 or in the *Aphelaspis* zone of the Llano uplift of central Texas. The writer (1954, pl. 26, fig. 27) figures a pygidium from boulder BM-4 very similar to the one associated by Kobayashi with the *T. longifrons* cranidium (Kobayashi 1938, pl. 16, fig. 26). See Plate 146, figure 19,20 (pyg).

DUNDERBERGIA CANADENSIS Kobayashi
Pl. 146, fig. 22

This species occurs with *Olenaspella evansi* in the Canadian material and somewhat resembles *D. nitida*, the type species from the higher *Aphelaspis* or sub-*Elvinia* fauna of the lower Dunderberg shale in the Eureka mining district, Nevada. A quite different species of the genus, *D. varigranula*, occurs both in the Dunderberg and in the *Aphelaspis* and post-*Aphelaspis* zone of the Llano uplift (Palmer, 1954, p. 761). The genus *Dunderbergia* has not been found in boulder BM-4.

The general association of the species discussed above leads the writer to believe that Kobayashi's *Dunderbergia*, *Taenicephalus* and *Parabolinella* limestones from the locality west of Harrogate all belong to the same general trilobite zone, namely the transition fauna between the *Aphelaspis* and *Elvinia* zones.

COMPARISONS WITH SPECIES DESCRIBED BY PALMER IN 1954 AND 1956

"PTEROCEPHALINA" cf. P. GRATA = LABIOSTRIA PLATIFRONS Palmer?

The type species of *Pterocephalina* Resser, 1938, *P. bilobata* (Hall and Whitfield 1877), was based upon a pygidium. This pygidium is conspecific with that belonging to "*Dicellocephalus*" *richmondensis* Walcott 1884, the specimens of which Resser had used the year previously, 1937, to found the genus *Litocephalus*. See A. R. Palmer (1956, p. 608, pl. 72) for complete discussion of this form. The name *Pterocephalina* is therefore invalid for numerous cranidia which are quite different from that of *Litocephalus* and were erroneously associated by Resser with the "*Pterocephalina*" *bilobata* type of pygidium. These cranidia are distinctive and

may belong to a new genus. The cranidia from Woods Hollow boulders BM-4 and BM-2 are not too dissimilar to the species *Labiostria platifrons* Palmer 1954 but are doubtfully assigned to this species because of insufficient material and lack of a pygidium.

APHELASPIS sp. undet.
Pl. 146, fig. 3,9,10

The writer does not wish to describe a new species on one cranidium from material unplaced in a measured section. However, a specimen collected in 1955 from Boulder BM-4, labeled CW-350, represents a species probably distinct from any described by Palmer from the *Aphelaspis* zone of the Lion Mountain. It possesses the faintly furrowed, tapered and truncate glabella, and medially located eyes with large semicircular palpebral lobes of *Aphelaspis*. The border is about half as long axially as the brim, arcuate, and is much more distinct than on most *Aphelaspis* species, most resembling that of *A. constricta* Palmer. Two distinct pits may appear at the anterolateral glabellar corners. Most distinctive is the elevated fixed cheek and palpebral lobe. Posterior limbs are not known. Except for the well-formed border this species could be assigned to Palmer's genus *Dytremacephalus*.

The specimen assigned by the writer (1954, pl. 26, fig. 17) to *Aphelaspis* cf. *A. walcotti* also from boulder BM-4 may belong with this species. Other cranidial fragments from the Welge-Lion Mountain sandstone beds in the Fish Drilling Company #1 Postell well of Kinney County, Texas figured (Plate 146, figures 9,10) probably belong also to this species. Specimens from depths 5039–40 and 5044–45 are figured.

DYTREMACEPHALUS LAEVIS Palmer
Pl. 146, fig. 13

Dytremacephalus laevis PALMER, 1954, Jour. Paleont., vol. 28, no. 6, p. 750, pl. 85, fig. 1–4.

The specimen figured is from 10 feet below the top of the Bolsa quartzite, Blue mountain section, Chiricahua-Dos Cabezas area, southeastern Arizona and was furnished by F. Sabins. It appears to agree in essential characters with Palmer's species. The fragmentary cranidia illustrated above as *Aphelaspis* sp. undet. may belong to a species of *Dytremacephalus*.

TREMPEALEAUAN OR HIGH FRANCONIAN TRILOBITE FROM 1955 BOULDER BM-9

RICHARDSONELLA sp. undet.
Pl. 146, fig. 4–6

Material consists of four fragmentary cranidia (two quite small) and a few fragments of free cheeks all from one small boulder less than 6 inches in diameter. Despite the poor material enough is present to show the characteristic palpebral lobes, furrowed quadrate glabella and peculiar indentation of the anterior facial suture just in front of the palpebral lobe. This small boulder (BM-9) contains the only fauna discovered which may be of Trempealeauan age. *Richardsonella* is known from the Gorge formation, from Franconian or Trempealeauan boulders in the Canadian Levis formation and associated with *Euptychaspis*, *Parabriscoia*, and *Leiocoryphe* species in lower Pogonip (= Windfall formation) limestone above the Dunderberg shale in the Eureka district (Kobayashi, 1935, p 41).

CORRECTIONS TO SPECIES FROM THE LOWER ORDOVICIAN (TREMADOCIAN) BEDS OF THE BASAL MARATHON FORMATION

Geragnostus "cranidium."—Dr. A. R. Palmer has called to the writer's attention that he (Wilson, 1954, pl. 26, fig. 16) has mistakenly illustrated a fragmentary pygidium of *Geragnostus* as a cranidium. The fragment is undoubtedly a spinose pygidium.

"*Asaphellus*" cranidium and "*Trigonocerca*" pygidium.—A communication from Dr. R. J. Ross, U. S. Geological Survey, Paleontology and Stratigraphy branch, suggests that the triangular-shaped pygidia from the section four miles south of Marathon termed *Trigonocerca* by the writer actually belong to the "*Asaphellus*" cranidia as indicated by their close association and that this genus is thus actually properly referable to the South American genus *Kayseraspis*.

"*Andesaspis argentinensis*."—The writer is grateful to Prof. H. J. Harrington of the University of Buenos Aires for the correction of this specific name to its proper one: *Parabolinopsis mariana* Hoek. Prof. Harrington writes:

Kobayashi proposed his genus *Andesaspis* on detached cranidia, free cheeks, and pygidia. He did not designate holotype but as he relied upon the cranidia for the assignment of *Andesaspis* to the olenidae, Harrington and Leanza (*La classification de los Olenidae y de los Ceratopygidae*, Rev. Asoc. Geol. Arg., vol. 7, no. 3, p. 196, 1953) designated the cranidium figured by Kobayashi in this plate XI, fig. 1 as lectotype. With this designation, *Andesaspis argentinensis* Kob. automatically becomes a synonym of *Parabolinopsis mariana* Hoek (The pygidium figured by Kobaysahi belonging to *Pseudokainella lata* Kobayashi).

Parabolinella "triarthroides."—Prof. H. Harrington, following recent study of early Ordovician olenids, informs the writer that the writer's fragmentary specimen assigned to *P. triarthorides* (Wilson, 1954, p. 280) is more properly assignable to *Parabolinella* ("*Moxomia*") *hecuba* (Walcott) because it lacks an expanded glabella and possesses slightly curved glabellar furrows.

"*Platycolpus*" cf. *P. capax* (Billings).—Lochman (1953, p. 889) proposes *Rasettia* to replace *Platycolpus* Raymond, 1913, which is a homonym of *Platycolpus* Donald, 1900, so that the writer's specimen (1954, p. 274, pl. 27, fig. 5–8) is properly designated *Rasettia* cf. *R. capax* (Billings).

FRAGMENTAL SPECIMENS FROM THE DAGGER FLAT FORMATION 4 MILES SOUTHWEST OF MARATHON, TEXAS

In 1954 the writer presented a faunal list of an olenid fauna occurring 225 feet below the Lower Ordovician (Tremadocian) lower Marathon formation (1954, p. 252), but these specimens were not illustrated or described in hopes that a better collection could be obtained. Further searching has revealed nothing except a few more agnostid pygidia. These include pygidia of *Geragnostus rudis* Salter, *Litagnostus*, and *Pseudagnostus* (Plate 146, figure 7,11,12). Fragmentary *Geragnostus* cranidia are also present but not illustrated.

A very small poor fragment of the anterior end of a convex and arcuate cranidium is figured with a convex, thickened border and apparently a short, almost tumid glabella. Although the well-formed ocular ridges of *Ctenopyge* are not present, the writer assigns this fragment to the genus. A tiny and possibly immature spinose pygidium is present (Plate 146, figure 14) and probably affores the best evidence that this fauna is a Cambrian olenid assemblage. It also is considered to belong to the genus *Ctenopyge* (Westergård, 1922, pl. 12,13). A typically olenid free cheek with the genal spine far out on the lateral margin also occurs in the collection but is not figured. The spine on the cheek drapes posteriorly and is not arcuate forward as in some species of *Ctenopyge*.

The foregoing nomenclatorial revisions necessitate bringing the faunal lists presented by the writer in 1954 up to date:

1. *Boulder type 3.* Early Ordovician fanua: List as presented except *Platycolpus* cf. *P. capax* = *Rasettia* cf. *R. capax; Parabolinella triarthroides?* = *P.* (*Moxomia*) *hecuba.*
2. *Lower Marathon formation* in section 4 miles southwest of Marathon, collection 3: *Kayseraspis* sp., *Symphysurina* cf. *S. woosteri, Beltella latifrons, Tostonia, Ophileta, Finkelnburgia;* collection 2: *Parabolinopsis mariana* Hoek; collection 1: *Ctenopyge?* cranidial fragment, *Ctenopyge?* pygidium of possibly immature form, *Geragnostus rudis, Litagnostus* sp. undet. and *Pseudagnostus* sp. undet., mainly pygidia.
3. *Boulder type 1955 BM-9* Trempealeauan or latest Franconian: *Richardsonella* sp. undet.
4. *Boulder type 4*—Middle Franconian, no identification changes: *Taenicephalus, Wilbernia? minuta, Bemaspis dubita, Pseudagnostus josephus.*
5. *Boulder type 5*—SS-26, SS-27, BM-new; lower Franconian? Total fauna: *Olenus? incertus, Olenus* cf. *O. truncatus, Pseudagnostus.*
6. *Boulder type 6:* BM-2 and BM-4, *Aphelaspis—Dunderbergia* zone. *Olenus* sp., *Olenus* cf. *O. truncatus, Olenaspella evansi, Labiostria platifrons? "Taenicephalus" megalops* Kobayashi, *Aphelaspis* sp. undet. (probably two species), one close to *Dytremacephalus, Aphelaspis* cf. *A. walcotti, Pseudagnosus cyclopyge, Homagnostus obesus, Glyptagnostus* (fragment only).
7. *Boulder type 7,* BM-10, 1955—Lowest Dresbachian or uppermost Middle Cambrian: *Blountia assimilis, Armonia* sp. undet., *Bolaspidella macgerriglei.*

Cedaria zone boulders, already listed in 1954, p. 260: *Cedaria* aff. *C. gaspensis, Blountia assimilis, Blountia ovata, Blountiella* sp., *Blountina* aff. *B. westoni, Coosella* sp., *Coosia pernamagna, Nasocephalus nasutus, N. flabellatus, Kormagnostus* sp., *Homagnostus* sp., *Pseudagnostus* sp.

REFERENCES

HOWELL, B. F., & DUNCAN, D., 1939, Middle-Upper Cambrian transition faunas of North

America: Bull. Wagner Free Inst. Sci., vol. 14, no. 1, p. 1–11, pl. 1.

KOBAYASHI, T., 1935, The *Briscoia* fauna of the late Upper Cambrian in Alaska with descriptions of a few Upper Cambrian trilobites from Montana and Nevada: Jap. Jour. Geol. Geogr., vol. 12, no. 3–4, p. 39–57, pl. 8–10.

—, 1936, On the *Parabolinella* fauna from Province Jujuy, Argentina with a note on the Olenidae: Jap. Jour. Geol. Geogr., vol. 13, no. 1-2, p. 85–102, pl. 15,16.

—, 1938, Upper Cambrian fossils from British Columbia with a discussion on the isolated occurrence of the so-called "*Olenus*" beds of Mt. Jubilee: Jap. Jour. Geol. Geogr., vol. 15, no. 3–4, p. 151–192, pl. 15,16.

—, 1943, Cambrian faunas of Siberia: Jour. Fac. Sci., Tokyo Univ., sec. 2, vol. 6, pt. 12, p. 271–334, pl. 1–3.

LOCHMAN, CHRISTINA, 1953, Analysis and discussion of nine Cambrian trilobite families: Jour. Paleont., vol. 27, no. 6, p. 889–896.

—, & DUNCAN, D., 1944, Early Upper Cambrian faunas of central Montana: Geol. Soc. Amer., Spec. Pap. No. 54, 173 p., 19 pl.

NORTH, F. K., & HENDERSON, G. G. L., 1954, Summary of the geology of the southern Rocky Mountains of Canada: Guide Book, 4th Ann. Field Conf., Alberta Soc. Petrol. Geol., p. 15–82.

PALMER, A. R., 1954, The faunas of the Riley formation in central Texas: Jour. Paleont., vol. 28, p. 709–786, pl. 76–92.

——, 1956, The type species of Litocephalus Resser 1937 (Tribolita): Jour. Paleont., vol. 30, p. 608–610, pl. 73.

SHAW, A. B., 1952, Paleontology of northwestern Vermont. II fauna of the Upper Cambrian Rockledge conglomerate near St. Albans: Jour. Paleont., vol. 26, p. 458–483, pl. 57.

WESTERGÅRD, A. H., 1922, Sveriges olenidskiffer: Sver. Geol. Undersökning, Ser. Ca., no. 18, 189 p., 16 pl.

——, 1953, Non-agnostidean trilobites of the Middle Cambrian of Sweden III: Sver. Geol. Undersökning, Ser. c, no. 526, p. 1–58, pl. 1–8.

WHITEHOUSE, F. W., 1939, The Cambrian faunas of northeastern Australia, pt. 3: Mem. Queensland Mus., no. 11, pt. 3, Brisbane.

WILSON, J. L., 1954, Late Cambrian and Early Ordovician trilobites from the Marathon uplift, Texas: Jour. Paleont., vol. 28, p. 249–285, pl. 24–27.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1350–1359, 1 TEXT-FIG., NOVEMBER 1956

THE INDEX VALUE OF SILURIAN FORAMINIFERA AND SOME NEW FORMS FROM WELLS IN KANSAS

HALSEY W. MILLER, JR.
Lawrence, Kansas

ABSTRACT—Two new species of Foraminifera, *Ammodiscus leei* and *Arenospihon rugosa*, from Kansas are described, and two new forms are described from subsurface samples but not named. The index value of Silurian Foraminifera is restricted to correlation of series because of incomplete knowledge of geographic and stratigraphic range. A chart showing the stratigraphic and geographic range of all species of Silurian Foraminifera described from North America is appended.

INTRODUCTION

W. L. MOREMAN (1930, 1933) published the pioneer work on Silurian and Ordovician Foraminifera from Oklahoma. This was followed by Eisenack's study (1932, 1937) of Baltic Silurian Foraminifera, Ireland's paper (1939) on Devonian and Silurian Foraminiferia from Oklahoma, Grubb's work (1939) on Niagaran Foraminifera from Illinois, Stewart & Priddy's study (1941) of Niagaran Foraminifera from Ohio and Indiana, and Dunn's paper (1942) on Silurian Foraminifera of the Mississippi basin.

The previous authors have written little (Ireland, 1939, p. 192) or nothing of polymorphism in Silurian Foraminifera. They have, however, described several species of a single genus from the same formation. When modern taxonomic procedures are applied to living faunas, rarely is more than one species of agenus found in a given ecologic niche at one locality. Explanation of the fossil assemblages may be: (1) the fauna represents a thanatocoenose, related species from other nearby environments being transported to the place of depsition. Transportation of foraminifera is readily possible, but should be indicated by size sorting. (2) Some of the "species" are in reality dimorphic forms and should be combined. (3) Micro-paleontologic taxonomy is much too fine and the species concept should be broadened. It is quite probable that all three of the above explanations apply to the problem of excess species; however, micropaleontologists working with Paleozoic foraminifers rarely cite them in explanation of "overspeciation" and seem to be unaware of any problem in this respect.

Dimorphic forms of two species of arenaceous Foraminifera are described in this paper, in order to explain the occurrence of two different forms of congeneric Foraminifera in the subsurface "Hunton limestone" of Kansas. No evidence of size sorting or "washing in" of specimens of either form was found.

FORAMINIFERA FROM WELLS IN KANSAS

The writer was recently given a set of 60 specimens of arenaceous Foraminifera by Wallace Lee of the Kansas Geological Survey. Mr. Lee collected the specimens from insoluble residues of the "Hunton limestone" (Moore et al., 1951, p. 117).

Ireland (1939, p. 192) listed the genera *Lituotuba* and *Ammodiscus* as Silurian index fossils in the "Hunton limestone" of Oklahoma. None of Ireland's Devonian index species for the "Hunton limestone" of Oklahoma were found in the Kansas well samples. In Kansas the name "Hunton limestone" is applied to a subsurface dolomite-limestone unit of Silurian and Devonian age. The "Hunton limestone" has a maximum thickness of 650 feet in Nemaha County. The Devonian and Silurian rocks in the "Hunton" limestone are separated by an unconformity that resulted from hundreds of feet of pre-Devonian erosion (Moore et al., 1951, p. 112). The presence of *Lituotuba inflata* Ireland in the McKnab No. 1 Fritz well may tend to confirm a Chimneyhill age for at least part of the "Hunton limestone" although correlation on this basis alone is doubtful.

Wallace Lee has used the base of the sandy zone in the "Hunton limestone" as a marker for the base of the Devonian. Chart I shows the depths to the top and bottom of the "Hunton limestone," the base of the Devonian sand zone, and the top of the

Silurian foraminiferal zone. A good accordance of these zones is found.

The Foraminifera are from the following localities: Empire No. 1 Schwalm well, SE¼ sec. 19, T. 12, S., R. 11 E., Wabaunsee County, Kansas, from a depth of 3,053 to 3,096 feet, in the "Hunton limestone"; McKnab No. 1 Fritz well, sec. 4, T. 12 S., R. 14 E., Shawnee County, Kansas, from a depth of 2,368 to 2,388 feet, in the "Hunton limestone"; and Coronado No. 1 Parks well, sec. 16, T. 10 S., R. 8 E., Riley County, Kansas, from a depth of 1,620 to 1,635 feet, in the "Hunton limestone."

Two new genera of the family Saccamminidae are described, one with megalosphaeric and microsphaeric forms, a new species of *Ammodiscus* is described, and the megalosphaeric and microsphaeric forms of a new species of *Arenosiphon* are described. The new genera remain unnamed because they have been found in subsurface samples from rotary wells. This leaves reasonable doubt as to their stratigraphic level, and other collectors cannot easily find similar specimens. These genera may be discovered later in an outcrop and named, or they may be named if it is proved that they come from a formation that does not crop out.

RANGE OF SILURIAN FORAMINIFERA WITHIN THE "HUNTON LIMESTONE"

Well	Empire No. 1 Schwalm	McKnab No. 1 Fritz	Coronado No. 1 Parks
Top of "Hunton limestone"	2990	2290	1290
Base of Devonian sandy zone	3050	2350	1310
Top of Silurian foram zone	3053	2368	1620
Base of "Hunton limestone"	3215	2415	1690

Depths in feet from sample logs by Wallace Lee.

SYSTEMATIC DESCRIPTIONS of Kansas Silurian Foraminifera

Family SACCAMMINIDAE

New Genus A

Text-fig. 1—5,6

The test is free, has a thick wall with annulations on the surface, and is flattened. The aperture may be on the blunt end of the test, but it has not been observed. The test has an overall "horn" shape and is composed of coarse well cemented quartz sand grains. Overall measurements are, length 1 mm.±, width 0.3 to 0.5 mm. The proloculs is not evident and the test seems to have one large, flattened chamber.

This new genus differs from previously described genera of Saccamminidae in having a thick annulated test and a distinctive "horn" shape. Ireland's genus *Ceratammina* has a smooth test, although the general outline is somewhat similar.

The range of this genus is the subsurface "Hunton formation" in Kansas.

Text-figures 1—5,6, are from the McKnab No. 1 Fritz well, Shawnee County.

New Genus B

Text-fig.1—7–11

The test is free, has a thick wall composed of coarse quartz sand grains, and a single chamber, which is constricted at irregular intervals. Initial coiling is planispiral, the initial coil being open (0.52 mm. diameter) in the microsphaeric form. There are no gradational specimens between these dimorphic forms. The second coil is tangent to the first, grown irregularly in some individuals, and is 0.22 mm. thick.

The outside of the test is rough and irregularly annulated. The aperture is at the end of the uncoiled portion of the tube and seems to be simple and round.

This genus differs from other genera of Saccamminidae in possessing a coiled early portion and a terminal aperture on an uncoiled "neck." It may be distinguished from *Ammodiscus* and *Tolypammina* by its lack of a second chamber. The range of this genus is the subsurface "Hunton limestone" of Kansas.

Megalosphaeric specimens are figures 7 and 8, microsphaeric specimens are figures 9–11 from Empire No. 1 Schwalm well, Wabaunsee County.

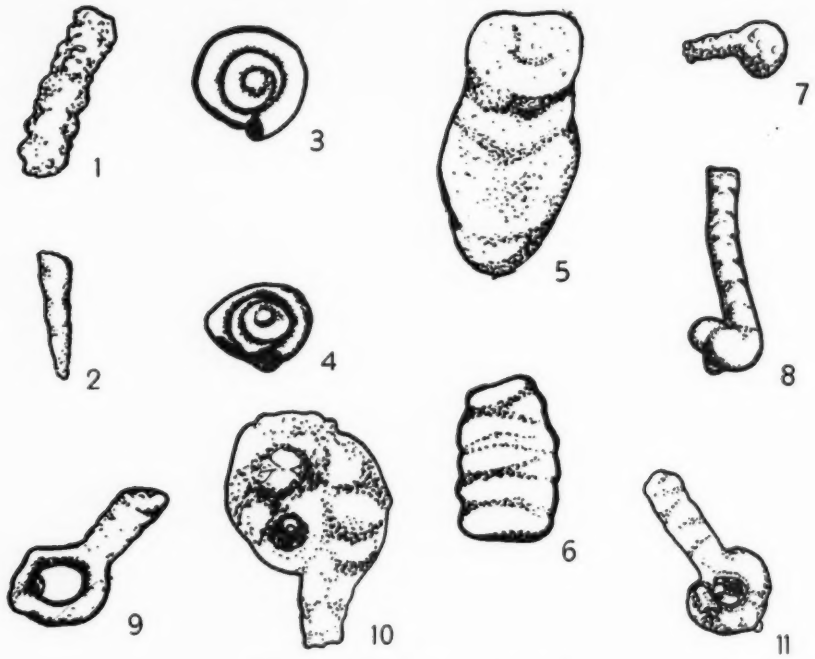
Family AMMODISCIDAE

AMMODISCUS Reuss 1861

AMMODISCUS LEEI Miller, n.sp.

Text-fig. 1—3,4

Test free, thin wall of well cemented fine quartz sand grains. The long undivided sec-



EXPLANATION OF TEXT-FIGURE 1

1—*Arenosiphon rugosa* Miller. Holotype, in paleontological collection of Kansas University, Microsphaeric form. (×50)
2—*Arenosiphon rugosa* Miller. Megalosphaeric form. Specimen in paleontological collection of Kansas University. (×50)
3—*Ammodiscus leei* Miller. Specimen in Kansas University paleontological collection. (×35)
4—*Ammodiscus leei* Miller. Holotype, the specimen is in the paleontological collection of Kansas University. (×35)
5—New genus A. Specimen in Kansas University collection. (×30)
6—New genus A. Specimen in Kansas University collection. (×30)
7—New genus B. Megalosphaeric form, specimen in Kansas University collection. (×30)
8—New genus B. Megalosphaeric form. (×30)
9—New genus B. Microsphaeric form. Specimen in Kansas University paleontological collection. (×30)
10—New genus B. Microsphaeric form. (×30)
11—New genus B. Microsphaeric form. All the above specimens are in the paleontologic collection of the Department of Geology, University of Kansas, Lawrence. (×30)

ond chamber is planispirally coiled around an ovoid proloculus. The mean diameter of the test is about 0.4 mm. The adult test has three complete whorls.

This species of *Ammodiscus* differs from other species in possessing only three whorls at a diameter of 0.4 mm. There is no uncoiling of the third volution, as in *Ammodiscus brevitubus* Dunn, although the species are otherwise similar. The range of this species is the subsurface "Hunton limestone" of Kansas.

This species is named in honor of Mr. Wallace Lee of the Kansas State Geological Survey.

Figures 3 and 4 are of specimens from the McKnab No. 1 Fritz well, Shawnee County.

LITUOTUBA Rhumbler 1895
LITUOTUBA INFLATA Ireland

Lituotuba inflata IRELAND, 1939, Jour. Paleont. vol. 13, p. 210.

This species was previously reported from the Chimney hill limestone of the "Hunton formation" in Oklahoma by Ireland. This occurrence extends its range to the subsurface

"Hunton limestone" of Kansas, and tends to confirm a Chimneyhill age for at least part of the "Hunton limestone" in Kansas. The specimen is from the McKnab No. 1 Fritz well, Shawnee County.

Family RHIZAMMINIDAE
ARENOSIPHON Grubbs 1939
ARENOSIPHON RUGOSA Miller, n. sp.
Text-fig. 1—1,2

The microsphaeric form has a thick cylindrical free test composed of cemented coarse quartz grains. The test is straight and tapers slightly. Overall measurements are, width 0.21 mm., length 0.5 mm.(+), ends of test broken off. The test may have had terminal apertures.

The megalosphaeric form has a free test composed of fine quartz grains cemented to form a thin cylindrical tube. The surface is smoother than that of the microsphaeric form. Overall measurements are, width 0.14 mm., length 0.35 mm.(+), ends of test broken off.

This species may be distinguished from *Arenosiphon gigantea* Grubbs by its smaller size. *A. gigantea* Grubbs has a mean width of 1.0 mm.

The range of this species is the subsurface "Hunton limestone" of Kansas. *A. gigantea* Grubbs is of Niagaran (Racine?) age.

Figure 1 is the microsphaeric form and figure 2 is the megalosphaeric form, from the Coronado No. 1 Parks well, Riley County.

All the type and figured specimens described above are in the University of Kansas Geological Museum.

VALUE OF SILURIAN FORAMINIFERA AS INDEX FOSSILS

Only a few lower Paleozoic formations have been thoroughly studied for their foraminiferal content. Perhaps the Chimneyhill limestone fauna of Oklahoma is the best known. There are no species recorded from the upper Silurian and very few species have been found in the Ordovician and Devonian. Future work in these rocks will undoubtedly result in the discovery of new species and extend the ranges of previously described genera and species.

A lower Paleozoic formation may be safely correlated with its series on the basis of a contained arenaceous foraminiferal fauna of a dozen or so species. Correlations based on a single species are dubious, as the ranges of individual species are not yet well enough known. Neither is the correlation

CORRELATION CHART OF FORAMINIFERA-BEARING SILURIAN ROCKS

		Kansas	Oklahoma	Indiana	Ohio	Illinois	Missouri
	CAYUGAN						
SILURIAN	NIAGARAN		Henryhouse			Bainbridge	Bainbridge
					Durbin gr.		
				Laurel & Massie	Laurel & Waldron	Joliet	
			St. Clair	Osgood			
				Dayton	Osgood		
	ALBION	Hunton (lower part) -----?-----?-----	Chimneyhill			Brassfield	Brassfield
						Edgewood	

TABLE 1—DISTRIBUTION OF SILURIAN ARENACEOUS FORAMINIFERA

	Ordovician		Albion				Niagaran																	
	Arbuckle	Viola	Edgewood	"Hunton"	Chimney Hill	Brassfield	Dayton	Osgood	St. Clair	Massie	Waldron	Laurel	Joliet	Bainbridge	Henryhouse	Niagaran	Dev.	Okla.	Ill.	Ind.	Mo.	Kans.	Ken.	Tenn.	Ohio
Ammodiscus incertus d'Orbigny					×		×	×										×		×	×				
Ammodiscus exsertus Cushman					×		×	×										×		×	×				×
Ammodiscus furca Moreman					×			×										×	×		×				
Ammodiscus constrictus Dunn													×						×						
Ammodiscus brevitubus Dunn								×											×						
Ammodiscus leei Miller				×																		×			
Ammodiscus minutus Dunn								×													×				
Ammodiscus abbreviatus Ireland					×													×							
Ammodiscus exsertus minutus Ireland					×													×							
Ammosphaeroides scotti Dunn								×													×				
Amphitremoidea spp. Eisenack																									
Arenosiphon gigantea Grabbs																×			×						
Arenosiphon rugosa Miller				×																		×			
Bathysiphon currus Moreman					×	×		×				×						×	×	×					
Bathysiphon deminutionis Moreman					×			×				×						×		×					
Bathysiphon exiguus Moreman		×				×		×				×				×		×	×	×					
Bathysiphon parallelus Dunn								×													×				
Bathysiphon currus gracilis Ireland					×													×							
Bathysiphon rugosus Ireland															×		×	×							
Bifurcammina bifurca Ireland					×													×							
Bifurcammina conjuncta Ireland					×													×							
Bifurcammina parallela Ireland					×													×							
Blastammina spp. Eisenack																									
Chitinodendron spp. Eisenack																									
Colonammina verruca Moreman					×													×							
Colonammina conea Moreman					×													×							
Colonammina bituba Dunn														×							×				
Crithionina rara Moreman					×													×							
Croncisella typa Dunn						×		×											×		×				
Gastroammina williamsoe Dunn								×													×				
Glomospira biplana Moreman					?													×							
Glomospira westgatei Ireland					×													×							
Glomospira siluriana Ireland					×													×							
Hyperamina minuta Moreman	×																	×							
Hyperammina bastula Moreman					×			×										×	×						
Hyperammina sublaevigata Dunn														×							×				
Hyperammina harrisi Ireland					×													×							
Kerionammina favus Moreman		×																×							

TABLE *1*—(*continued*)

	Ordovician		Albion				Niagaran																				
	Arbuckle	Viola	Edgewood	"Hunton"	Chimney Hill	Braesfield	Dayton	Osgood	St. Clair	Massie	Waldron	Laurel	Joliet	Bainbridge	Henryhouse	Niagaran	Dev.	Okla.	Ill.	Ind.	Mo.	Kans.	Ken.	Tenn.	Ohio	Baltic
Ammodiscus ephoerica Moreman					×			×											×		×					
Ammodiscus stilla Moreman					×								×					×	×							
Ammodiscus cucurbita Moreman					×													×								
Ammodiscus bulbosa Dunn						×		×											×							
Ammodiscus uniformis Dunn								×								×					×			×		
Ammodiscus cornuta Grubbs																×			×							
Ammodiscus distorta Ireland					×													×								
Bisphaera exerta Moreman					×		×	×						×		×		×	×	×	×				×	
Bisphaera inflata Ireland				×	×		×											×				×			×	
Bisphaera salinensis Dunn								×											×							
Bisphaera? furca Dunn													×						×							
Bisphaera elongata Dunn								×													×					
Bisphaerigilla aggregata Moreman		×																×								
Bisphaerigilla? torta Stewart & Priddy								×												×						
Bisphaerina spp. Eisenack																										×
Bisphaerinella? lineata Grubbs																×			×							
Bisphaerina jolietensis Dunn						×													×							
Bisphaerina acuta Dunn								×											×							
Bisphaerina? ornata Dunn						×													×							
Bisphaerodendron? sp. Eisenack																										×
Bisphaerosphaera cava Moreman					×			×										×		×	×					×
Bisphaerosphaera subsphaerica Stewart & Priddy									×																×	
Bisphaerosphaera arcuata Dunn					×														×							
Bisphaerosphaera conjunctiva Dunn								×													×					
Bisphaerosphaera excerpta Dunn								×											×							
Bisphaerosphaera gigantea Dunn						×		×											×					×		
Bisphaerosphaera minuta Dunn													×								×					
Bisphaerosphaera compressa Dunn													×								×					
Bisphaerosphaera angularis Ireland					×																					
Bisphaerosphaera gracilis Ireland									×						×			×								
Bisphaeroturbina irregularis Dunn			×					×											×		×					
Bisphaeroturbina regularis Dunn						×		×											×		×					
Bisphaerina mica Moreman		×																×								
Bisphaerina aspera Moreman		×						×										×			×					
Bisphaerina irregularis Stewart & Priddy								×											×							
Bisphaerina trifurcata Moreman		×						×										×								
Bisphaerina geniculata Stewart & Priddy								×										×		×						

TABLE 1—(*continued*)

	Ordovician		Albion				Niagaran																	
	Arbuckle	Viola	Edgewood	"Hunton"	Chimney Hill	Brassfield	Dayton	Osgood	St. Clair	Massie	Waldron	Laurel	Joliet	Bainbridge	Henryhouse	Niagaran	Dev.	Okla.	Ill.	Ind.	Mo.	Kans.	Ken.	Tenn.	Ohio
Rhabdammina minuta Stewart & Priddy								×										×		×					
Rhabdammina triradiata Stewart & Priddy								×												×					
Saccammina binosculata Moreman					×													×							
Saccammina aspera Stewart & Priddy												×								×					
Saccammina moremani Ireland					×													×							
Shidelerella bicuspidata Dunn								×											×						
Shidelerella cylindrica Dunn														×							×				
Shidelerella elongata Dunn														×							×				
Sorosphaera tricella Moreman					×									×				×			×				
Sorosphaera osgoodensis Stewart & Priddy								×		×										×					×
Sorosphaera bicella Dunn						×								×		×			×		×				
Sorosphaera irregularis Grubbs																			×						
Sorosphaera multicella Dunn											×									×					
Sorosphaera subconfusa Dunn								×													×				
Stegnammina cylindrica Moreman					×													×							
Stegnammina cylindrica brevis Dunn						×															×				
Stegnammina elongata Ireland																	×	×							
Stegnammina hebesta Moreman					×													×							
Stegnammina triangularis Moreman					×													×							
Thekammina quadrangularis Dunn						×													×						
Thekammina moremani Dunn						×															×				
Tholosina conreza Moreman					×													×							
Tholosina? dubia Dunn														×							×				
Tholosina elongata Moreman		×																×							
Tholosina sedentata Ireland					×													×							
Thurammina arcuata Moreman								×				×							×	×					
Thurammina coronata Dunn														×							×				
Thurammina crescentrica Stewart & Priddy								×												×					
Thurammina cylindrica Grubbs																×			×						
Thurammina delicata Ireland					×													×							
Thurammina echinata Dunn								×					×	×					×		×				
Thurammina elliptica Moreman						×		×												×	×		×		
Thurammina foersteï Dunn						×													×						
Thurammina globosa Ireland					×													×							
Thurammina globula Grubbs																×			×						
Thurammina? hexactinellida Dunn						×		×											×						
Thurammina hexagona Dunn		×						×											×						

TABLE 1—(*continued*)

	Ordovician		Albion				Niagaran																				
	Arbuckle	Viola	Edgewood	"Hunton"	Chimney Hill	Brassfield	Dayton	Osgood	St. Clair	Massie	Waldron	Laurel	Joliet	Bainbridge	Henryhouse	Niagaran	Dev.	Okla.	Ill.	Ind.	Mo.	Kans.	Ken.	Tenn.	Ohio	Baltic
...mina inflata Dunn														×							×					
...mina irregularis Moreman					×			×					×						×							
...mina jubata Dunn													×			×					×			×		
...mina limbata Dunn														×							×					
...mina limbata disciformis Dunn						×													×							
...mina magna Dunn								×													×					
...mina mellevi Dunn													×						×							
...mina papillata Brady					×			×										×	×							
...mina papillata monticulifera Ireland					×			×										×	×							
...mina parituba Dunn								×											×							
...mina phasela Moreman								×													×					
...mina polygona Ireland					×													×								
...mina quadrata Dunn														×							×					
...mina quadritubulata Dunn														×							×					
...mina seminaformis Dunn						×													×		×					
...mina slocumi Dunn								×											×							
...mina sphaerica Ireland					×													×								
...mina spendens Dunn														×							×					
...mina stelliformis Dunn														×							×					
...mina subpapillata Ireland					×													×								
...mina subsphaerica Moreman					×								×					×	×							
...mina transversalis Ireland					×													×								
...mina tributa Dunn								×													×					
...mina tubulata Moreman					×									×				×			×					
...mina unitubula Grubbs																×			×							
...mina tortuosa Dunn						×															×					
...mina? prima Stewart & Priddy								×																	×	
...illella fisheri Dunn								×											×	×	×		×	×		
...illella workmani Dunn								×											×							
...illella osgoodensis Dunn								×											×							
...ella tholus Moreman		×																×								
...ella quadripartita Moreman																×		×								
...ella bipartita Ireland																×		×								
...ella coronata Ireland					×													×								
...ella gibbosa Ireland					×													×								
...ella spp. Eisenack																										×
...med genera A and B			×																		×					

of one formation with a distant formation on the basis of Foraminifera alone reliable, for the faunas of many formations are known only incompletely or not at all.

The seeming restriction of otherwise long-ranging genera to rocks of one age within the lower Paleozoic should not be used as a criterion for correlation as this may be caused by an affinity for a certain facies.

The writer concludes that one may use these Foraminifera for correlation if the above rules are observed.

The list of arenaceous Foraminifera given here includes the Ordovician, Lower and Middle Silurian, and Devonian "index" species. No one species in this list is to be relied upon as an exact index, but a group of several of these species may prove useful in this respect.

Ordovician Index Foraminifera

Hyperammina minuta Moreman
Kerionammina favus Moreman
Marsipella aggregata Moreman
Raibosammina mica Moreman
Rhabdammina trifurcata Moreman
Tholosina elongata Moreman
Webbinella tholus Moreman

Silurian Index Foraminifera

Species restricted to Albion:

Ammodiscus leei Miller
A. abbreviatus Ireland
A. exsertus minutus Ireland
Arenosiphon rugosa Miller
Bathysiphon curvus gracilis Ireland
Bifurcammina bifurca Ireland
B. conjuncta Ireland
B. parallela Ireland
Colonammina verruca Moreman
C. conea Moreman
Crithionina rara Moreman
Glomospira westgatei Ireland
G. siluriana Ireland
Hyperammina harrisi Ireland
Lagenammina cucurbita Moreman
L. distorta Ireland
Proteonina jolietensis Dunn
P.? ovata Dunn
Psammosphaera arcuata Dunn
P. angularis Ireland
Saccammina biosculata Moreman
S. moremani Ireland
Stegnammina cylindrica Moreman
S. cylindrica brevis Dunn
S. hebesti Moreman
S. triangularis Moreman
Thekammina quadrangularis Dunn
Thekammina moremani Dunn
Tholosina convexa Moreman
T. sedentata Ireland
Thurammina delicata Ireland
T. foerstei Dunn
T. globosa Ireland
T. limbata disciformis Dunn
T. polygona Ireland
T. seminiformis Dunn
T. sphaerica Ireland
T. subpapillata Ireland
T. transversalis Ireland
Tolypammina tortuosa Dunn
Webbinella coronata Ireland
W. gibbosa Ireland

Species restricted to Niagaran:

Ammodiscus constrictus Dunn
A. brevitubus Dunn
A. minutus Dunn
Ammosphaeroides scotti Dunn
Arenosiphon gigantea Grubbs
Bathysiphon parallelus Dunn
Colonammina bituba Dunn
Gastroammina williamsae Dunn
Hyperammina sublaevigata Dunn
Lagenammina urniformis Dunn
L. cornuta Grubbs
Lituotuba salinensis Dunn
L.? furca Dunn
L. elongata Dunn
Marsipella? torta Stewart & Priddy
Placopsilina ? lineata Grubbs
Proteonina acuta Dunn
Psammosphaera subsphaerica Stewart & Priddy
P. conjunctiva Dunn
P. excerpta Dunn
P. minuta Dunn
P. compressa Dunn
Raibosammina irregularis Stewart & Priddy
Rhabdammina geniculata Stewart & Priddy
R. minuta Stewart & Priddy
R. triradiata Stewart & Priddy
Saccammina aspera Stewart & Priddy
Shidelerella bicuspidata Dunn
S. cylindrica Dunn
S. elongata Dunn
Sorosphaera osgoodensis Stewart & Priddy
S. irregularis Grubbs
S. multicella Dunn
S. subconfusa Dunn
Tholosina ? dubia Dunn
Thurammina arcuata Moreman
T. coronata Dunn
T. crescentrica Stewart & Priddy
T. cylindrica Grubbs
T. echinata Dunn
T. globula Grubbs
T. hexagona Dunn
T. inflata Dunn
T. jubata Dunn
T. limbata Dunn
T. magna Dunn
T. melleni Dunn
T. parvituba Dunn
T. phasela Moreman
T. quadrata Dunn
T. quadritubulata Dunn

T. slocumi Dunn
T. splendens Dunn
T. stelliformis Dunn
T. tributa Dunn
T. unitubula Grubbs
Trochammina ? prima Stewart & Priddy
Turitellella fisheri Dunn
T. workmani Dunn
T. osgoodensis Dunn

DEVONIAN INDEX FORAMINIFERA

Stegnammina elongata Ireland
Webbinella quadripartita Moreman
Webbinella bipartita Ireland
Psammophax bipartita Ireland
Ceratammina cornucopia Ireland
Psammonyx maxwelli Ireland

REFERENCES

CUSHMAN, J. A., 1930, Notes on early Paleozoic Foraminifera: Contr. Cushman Lab. Foram. Res., vol. 6, p. 43–44, pl. 6.

——, 1935, Paleozoic Foraminifera, their relationships to modern faunas, and to their environment: Jour. Paleont., vol. 9, p. 284–287.

——, 1950, Foraminifera: Harvard University Press, Cambridge, 605 p., 55 pl.

DUNN, P. H., 1942, Silurian Foraminifera of the Mississippi Basin: Jour. Paleont., vol. 16, p. 317–342, pl. 42–44.

EISENACK, A., 1932, Neue mikrofossilien des baltischen Silurs. II (Foraminiferen, Hydrozoen, Chitinozoen, u.a.): Paleont. Zeitsch., vol. 14, p. 257–277, pl. 11–12.

——, 1937, Neue mikrofossilien des baltischen Silurs. IV Foraminiferen: Paleont. Zeitsch., vol. 19, p. 233–243, pl. 15–16.

GRUBBS, D. M., 1939, Fauna of the Niagaran nodules of the Chicago area: Jour. Paleont., vol. 13, p. 544.

IRELAND, H. A., 1939, Devonian and Silurian foraminifera from Oklahoma; Jour. Paleont., vol. 13, p. 190–202.

MOORE, R. C., FRYE, J. C., JEWETT, J. M., LEE, W., O'CONNOR, H. G., 1951, The Kansas Rock Column: Kans. Geol. Surv. Bull. 89, 132 p.

MOREMAN, W. L., 1930, Arenaceous Foraminifera from Ordovician and Silurian limestones of Oklahoma: Jour. Paleont., vol. 4, p. 42–59, pl. 5–7.

——, 1933, Arenaceous Foraminifera from the lower Paleozoic rocks of Oklahoma: Jour. Paleont., vol. 7, p. 393–397, pl. 49.

STEWART, G. A., & PRIDDY, R. R., 1941, Arenaceous Foraminifera from the Niagaran rocks of Ohio and Indiana: Jour. Paleont., vol. 15, p. 366–375, pl. 54.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1360–1366, NOVEMBER 1956

ADDENDUM TO A BIBLIOGRAPHY OF THE FAMILY FUSULINIDAE*

DONALD F. TOOMEY
Shell Development Company, Houston

ABSTRACT—An addition of 218 references to the fusulinid bibliography brings the total number of references pertaining to this group to 851. The additions may be considered reasonably complete to the year 1955, inclusive.

SINCE publication of the fusulinid bibliography Toomey (1954) numerous additional references have appeared; their inclusion in an addendum is deemed necessary to retain the usefulness of this bibliography.

The compiler wishes to acknowledge the fusulinid information received from Professors R. Toriyama and K. Kanmera concerning Japanese fusulinid publications, and F. F. Mellen for information on the fusulinids of the Black Warrior Basin.

It is believed by the compiler that the following addendum is reasonably complete; any significant omissions brought to his attention will be greatly appreciated.

1. AGATSTON, R. S., 1954, Pennsylvanian and lower Permian of northern and eastern Wyoming: Amer. Assoc. Petrol. Geol., Bull., vol. 38, p. 508–583, 18 fig.
2. ALEXANDER, R. D., 1954, Desmoinesian fusulinids of northeastern Oklahoma: Oklahoma Geol. Survey, Circ. 31, p. 1–67, 4 pl., 3 text-fig.
3. ARMSTRONG, J. E., 1949, Fort St. James map-area, Cassiar and Coasts districts, British Columbia: Canada Geol. Survey, Mem. 252, p. 1–210.
4. BAKER, A. A., HUDDLE, J. W., & KINNEY, D. M., 1949, Paleozoic geology of north and west sides of Uinta basin: Amer. Assoc. Petrol. Geol., Bull., vol. 33, p. 1179–1185.
5. BEEDE, J. W., 1900, Carboniferous invertebrates: Kansas Univ. Geol. Survey, vol. 6, p. 1–187. [*Fusulina secalica* described.]
6. ——, 1910, The correlation of the Guadalupian and Kansas sections: Am. Jour. Sci., 4th. ser., vol. 30, p. 131–140, 3 text-fig.
7. BERGENBACK, R. E., & TERRIERE, R. T., 1953, Petrography and petrology of Scurry reef, Scurry County, Texas: Amer. Assoc. Petrol. Geol., Bull., vol. 37, p. 1014–1029, 1 pl., 4 text-fig.
8. BLACKSTONE, D. L., 1954, Permian rocks in Lemhi Range, Idaho: *ibid.*, vol. 38, p. 923–925.
9. BOLKHOVITINOVA, M. A., 1937, The section at Myachkovo in the light of new paleontologic data: 17th. Internat. Geol. Cong. (Moscow), Abstracts of Papers Presented, p. 245–246. [Respective horizons of *Fusulinella bocki* (Möller) and *Fusulina cylindrica* Fischer discussed.
10. BOSTWICK, D. A., 1955, Stratigraphy of the Wood River formation, south-central Idaho: Jour. Paleont., vol. 29, p. 941–951, pl. 96–98, 1 text-fig.
11. BRADLEY, J. S., 1956, A tetratoid *Parafusulina: ibid.*, vol. 30, p. 303–305, pl. 40 C.
12. BURMA, B., 1940, Statistical analysis applied to fusulinids (Abstract): Oil & Gas Jour., vol. 38, no. 48, p. 67.
13. ——, 1953, Studies in quantitative paleontology. III. An application of sequential analysis to the comparison of growth stages and growth series: Jour. Geol., vol. 61, p. 534–538, text-fig. 2.
14. CADY, G. H., 1939, Significant uncertainties in Pennsylvanian correlation in Illinois Coal basin: Amer. Assoc. Petrol. Geol., Bull. vol. 23, p. 1523.
15. CARPENTER, W. B., 1870, On the shell structure of *Fusulina:* Mon. Micro. Jour. London vol. 3.
16. CHIZAKA, T., 1953, Fusulinidae from Yasakamura, Kisen-gun, Iwate prefecture: Geol. Soc. Japan, Jour., vol. 58, p. 312–313.
17. CHURCH, C. C., 1953, Foraminifera, an evaluation: Amer. Assoc. Petrol. Geol., Bull., vol. 37, p. 1553–1559.
18. CIRY, R., 1948, Un nouveau fusulinidé Permien: Bull. Sci. Bourgogne, tome. 11, p. 103–110, pl. 1.
19. ——, 1952, Fusulinoidea (In Piveteau, Traité de Paléont.: vol. 1, Paris (Masson), p. 177–191, text-fig. 42–54, 4 tables.
20. ——, 1954, Á propos de *Neoschwagerina syrtalis* Douvillé: Soc. Sci. Nat. Tunisie, Bull., vol. 7, p. 111–122, pl. 20.
21. CONDRA, G. E., REED, E. C., and SCHERER, O. J., 1950, Correlation of the formations of the Laramie range, Hartville uplift, Black Hills and western Nebraska: Neb. Geol. Survey, Bull. 13-A, p. 24–31. text-fig. 10.
22. CRANDALL, K. H., 1929, Permian stratigraphy of southeastern New Mexico and

* Publication No. 97, Shell Development Company, Exploration and Production Research Division, Houston, Texas.

adjacent parts of western Texas: Amer. Assoc. Petrol. Geol., Bull., vol. 13, p. 933, 935.

23. De Lapparent, 1902, Traité de Géologie: 3rd Ed., vol. 2, p. 819, 865,871. [Introduces the name Ouralian.]
24. De Marez Oyens, F. A. H. W., 1940, Over het voorkomen van *Fusulina*-Kalken in het Basleogebied: Geol. Instit. Mededeel., no. 110, Univ. Amsterdam, p. 1–3.
25. Dalmatskaya, I. I., 1951, Novyi vid fuzulinid iz nishnei chasti stednekamennougolnykh otlozhenii Russkoi platformy: Moskov. Obshch. Ispyt. Prirody, (Trudy), otdel geol. vol. 1, p. 194–196.
26. Darton, N. H., & Reeside, J. B., 1926, Guadalupe group: Geol. Soc. Amer., Bull., vol. 37, p. 413–428, pl. 12–16, text-fig. 1–5.
27. Dawson, G. M., 1878, Report on explorations in British Columbia, chiefly in the basins of the Blackwater, Salmon and Nechacco rivers, and on Francois Lake: Can. Geol. Survey, Rept. Prog. 1876–1877, pt. 3, p. 17–94.
28. Deleau, P., & Marie, P., 1956, Existence de Fusulinides dans le Westphalien C du Sud-Oranais (Algerie): Soc. geol. France, c. r., no. 12, p. 220–221.
29. Delepine, G., 1935, Le Carbonifère du Sud de la France (Pyrénées et Montagne Noire) et du Nord-Ouest de L'Espagne (Asturies): Cong. Strat. Carb. Heerlen 1935, c. r., vol. 1, p. 139–158.
30. Dott, R. H., 1954, *Chaetetes*, important marker in Pennsylvanian of central Great Basin (Abstract): Geol. Soc. Amer., vol. 65, p. 1245–1246.
31. ——, 1955, Pennsylvanian stratigraphy of Elko and northern Diamond ranges, northeastern Nevada: Amer. Assoc. Petrol. Geol. Bull., vol. 39, p. 2211–2305, 19 fig.
32. Drake, N. F., 1893, Report on the Colorado coal fields of Texas: Texas Geol. Survey, 4th. Ann. Rept. pt. 1, p. 355–446.
33. Dunbar, C. O., 1928, Fusulinidae as an aid in zoning the American upper Carboniferous strata (Abstract): Geol. Soc. Amer. Bull., vol. 39, p. 290–291.
34. ——, 1941, Permian faunas, a study in facies *ibid.*, vol. 52, p. 313–332, 8 text-fig.
35. ——, 1942, Artinskian series: Amer. Assoc. Petrol. Geol., Bull., vol. 26, p. 402–409, 3 text-fig.
36. ——, 1953, A giant Permian fusuline from Sonora (*In* Permian fauna at El Antimonio, western Sonora, Mexico): Smithsonian Misc. Coll. Publ. 4108, vol. 119, p. 14–19, pl. 2–3.
37. ——, 1953b, A zone of *Pseudoschwagerina* low in the Leonard series in the Sierra Diablo, Trans-Pecos Texas: Am. Jour. Sci., 5th ser., vol. 251, p. 798–813, 2 pl., 2 text-fig., 1 table. [First discovery of the genus *Pseudoschwagerina* above the Wolfcamp series in America and its first observed occurrence and association with *Parafusulina*.]
38. ——, 1954, A new technique for making sections of invertebrate fossils: Jour. Paleont., vol. 28, p. 112.
39. ——, 1954b, Comment regarding opinion 213 (genus "*Schwagerina*"). Internat. Comm. Zool. Nomenclat., Opinions and Declarations Rendered, vol. 4, pt. 3, p. 32–33.
40. ——, & Misch, P., 1947, Fusuline-bearing Permian rocks of northwestern Yunnan: Chin Geol. Soc., Bull., vol. 28, p. 101.
41. Dunham, R. J., 1955, Pennsylvanian conglomerates, structure, and orogenic history of Lake Classen area, Arbuckle Mountains, Oklahoma: Amer. Assoc. Petrol. Geol., Bull., vol. 39, p. 11–12.
42. Dyakonova-Saveleva, E. N., 1951, Genezis i stratigraficheskoe polozhenie krasnotsvetnoi tolshchi svernogo kavkaza v svyazi s nakhodkoi vysshikh fuzulinid: Leningrad obshch. est., (Trudy), otdel geol. vol. 68, p. 102–149, pl. 1, 16 text-fig.
43. Fliegel, G., 1902, Ist Karbonische Fusulinen-kalk von Borneo Ulkannt?: Deutsche geol. Gesell. Zeitschr., vol. 54, p. 117–118.
44. Fredericks, G., 1928, Le Paléozoique supérieur de l'Oural: Ann. de la Soc. Géol. du Nord, vol. 53, p. 138–171.
45. Fujii, K., 1954, Occurrence of *Profusulina* and *Cancellina* zones: Geol. Soc. Japan, Jour., vol. 60, no. 710, p. 494–500.
46. Fujimoto, H., 1936, Stratigraphical and paleontological studies of the Titibu system of the Kwanto-Mountainland: Pt. 2, Paleont. Tokyo Bunrika Daigaku, Sci. Repts., sec. C, vol. 1, p. 29–125, pl. 1–26.
47. ——, 1941, *Pseudoschwagerina* from Akasaka and its neighborhood and some considerations on the geological age of the *Pseudoschwagerina* zone of Japan: Geol. Soc. Japan, Jour., vol. 48, no. 569, p. 1–10, 1 pl.
48. ——, 1950, Fusulinids from Kuriyamamura, Tochigi prefecture and Tada-mura, Hyogo prefecture: *ibid.*, vol. 56, no. 657, 1 p.
49. ——, 1951, The fusulinid zones in the Japanese Carboniferous: 3rd. Congr. Advanc. Etudes Strat. et Géol. du Carbonifère, Heerlen, c. r., vol. 1, p. 219–223, 1 table.
50. ——, 1952, Fossil zones of Carboniferous and Permian in Japan: Geol. Soc. Japan, Jour., vol. 58, p. 318.
51. ——, 1956, A new species of *Parafusulina* from the Kitakami massif: Japan, Trans. Proc. Palaeont. Soc. Japan, n.s., no. 21, p. 157–160, pl. 25.
52. ——, *et al.*, 1950, Geological studies of the Oku-Chichibu: Chichibu Mus. Nat. Hist., Bull., no. 1, p. 1–27.
53. ——, & Igo, H., 1955, *Hidaella*, a new genus of the Pennsylvanian fusulinids from the Fukuji district, eastern part of the Hida mountainland, central Japan: Trans. Proc. Paleont. Soc. Japan, n.s., no. 18, p. 45–48, pl. 7.
54. ——, & Kawada, S., 1951, *Triticites* zone found in Orni-limestone, Niigata prefecture: Geol. Soc. Japan, Jour., vol. 57, p. 266–267.

55. ——, & ——, 1953, *Hayasakina*, a new genus of fusulinids from the Omi-limestone, Niigata prefecture, Japan, Tokyo Bunrika Daigaku: Sci. Repts., sec. C, vol. 2, p. 207–210, 1 pl.
56. GERASSIMOV, N. P., 1937, Ural division of the Permian system: Science Notes (Kazan Univ.) vol. 97, p. 3–68.
57. Gerth, H., 1915, Geologische und morphologische Beobachtungen in den Kordilleren Südperus: Geol. Rundschau, vol. 6, p. 129–153.
58. GILES, A. W., 1930, Pennsylvanian climates and paleontology: Amer. Assoc. Petrol. Geol., Bull., vol. 14, p. 1287–1290.
59. GILLULY, J., COOPER, J. R., & WILLIAMS, J. S., 1954, Late Paleozoic stratigraphy of central Cochise County, Arizona: U. S. Geol. Survey Prof. Paper 266, p. 33–37.
60. HAM, W. E., 1954, Collings Ranch conglomerate, late Pennsylvanian, in Arbuckle Mountains, Oklahoma: Amer. Assoc. Petrol. Geol., Bull., vol. 38, p. 2041–2042.
61. HANZAWA, S., 1954, Notes on *Afghanella* and *Sumatrina* from Japan: Japanese Jour. Geol. Geogr., vol. 24, p. 1–14, pl. 1–3.
62. ——, 1954b, Stratigraphic distribution of the fusulinid foraminifera in Japan: Congr. Geol. Internat. Alger 1952, 19th. Session, compte rendu, sect. 13, fasc. 15, p. 129–137, 1 table.
63. HAYASAKA, I., 1954, New occurrence of fusulinids from Formosa (Taiwan): Yukochu, no. 2, p. 5–6.
64. ——, et al., 1954b, Abstract of principal lectures and discussions of the symposium on the Permian system in Japan: Geol. Soc. Japan, Jour., vol. 60, no. 706, p. 302–304.
65. ——, & MATSUO, H., 1951, Permian fossils at Nojiri, Kamianamura, Fukui prefecture: *ibid.*, vol. 57, p. 266.
66. ——, & MINATO, M., 1952, Carboniferous formations in the Japanese islands: 3rd. Congr. Advanc. Etudes Strat. et Géol. Carbonifere, Heerlen, c. r., vol. 1, p. 267–274, 2 tables.
67. ——, & ——, 1952b, The Japanese Carboniferous (Abstract): 19th. Congr. Geol. Internat. Alger., Resumes des Communications, p. 112.
68. HEMMING, F., 1954, Opinion 213. Determination of the type species of the genus "*Schwagerina*" von Möller, 1877 (Class Rhizopoda, order Foraminifera): Internat. Comm. Zool. Nomenclat., Opinions and Declarations Rendered, etc., vol. 4, pt. 3, p. 25–40.
69. HENBEST, L. G., 1953, The name and dimorphism of *Endothyra bowmani* Phillips, 1846: Cushman Found. Foram. Res., Contr., vol. 4, p. 63–65, 2 text-fig.
70. HEYLMUN, E. B., 1953, Carboniferous fossils from wells in the Paradox basin: Amer. Assoc. Petrol. Geol., Bull., vol. 37, p. 2188–2191, 2 text-fig.
71. HOFFET, J. H., 1950, Notes sur le Geologie de la Province du Haute-Mikong: Indochine Service géol., Bull., vol. 29, fasc. 2, p. 1–21.
72. HORNIBROOK, N. de B., 1952, Fusulines of the Waipapa series, north Aukland peninsula: 19th. Congr. Geol. Internat. Alger. Symposium, Séries de Gondwana, p. 25.
73. JONES, D. J., 1956, Introduction to microfossils (Fusulinids- p. 196, 198, 200, text-fig 9-7 to 9-10, 11-1, 11-2): Harper & Brothers, New York.
74. KAHLER, F., 1934, Fusulinidae (aus Südwestpersien): Paleontographica, vol. 79, abt. A, p. 168–172.
75. ——, 1952, Über die Bruchfestigkeit einiger Typen von Fusulinenschalen: Osterreich. Akad. Wiss., Wien, Math,-naturwiss. Kl., vol. 160, p. 377–386.
76. ——, & KAHLER, G., 1935, Stratigraphische und Fazielle Untersuchungen im Oberkarbon und Perm der Karnischen Alpen: Cong. Strat. Carb. Heerlen 1935, c. r., vol. 1, p. 445–487, pl. 59–62, 3 text-fig.
77. KANMERA, K., 1952, The lower Carboniferous Kakisako formation of southern Kyushu with a description of some corals and fusulinids: Fac. Sci. Kyushu Univ., Mem., Ser. D, vol. 3, p. 155–177, pl. 8–12, 2 text-fig., 2 tables.
78. ——, 1952b, The upper Carboniferous and lower Permian of the Hikawa valley, Kumamota prefecture, Kyushu, Japan: Geol. Soc. Japan, Jour., vol. 58, p. 17–32, 4 test-fig.
79. ——, 1953, The stratigraphical and paleontological studies of the Kuma formation: *ibid.*, vol. 59, p. 362.
80. ——, 1953b, The Kuma formation, with special reference to the upper Permian in Japan: *ibid.*, p. 449–468, pl. 10, 5 text-fig.
81. ——, 1954, Fusulinids from the upper Permian Kuma formation, southern Kyushu, Japan- with special reference to the fusulinid zone in the upper Permian of Japan: Fac. Sci. Kyushu Univ., Mem., ser. D, vol. 4, p. 1–38, 6 pl., 2 text-fig.
82. KARPINSKY, A., 1874, Geologische Untersuchungen im Gouvernment Orenburg: Verh. Min. Gesellsch. (St. Petersbourg), vol. 9, p. 212–310. [First to propose the name Artinskian series.
83. KAWADA, S., 1954, Discovery of fusulinids in the Carboniferous corals from the Omi limestone in Niigata prefecture: Tokyo Nat. Sci. Mus., vol. 21, p. 1–6. [Concludes that late Paleozoic fusulinids were vagile benthonic forms.]
84. ——, & FUJIMOTO, H., 1952, Oomi limestone of Niigata prefecture; stratigraphical study of the Fusulinidae (Abstract): Geol. Soc. Japan, Jour., vol. 58, p. 320.
85. ——, & MORIKAWA, R., 1953, So-called *Parafusulina? japonica* and its stratigraphical significance: Tokyo Nat. Sci. Mus., vol. 20, p. 1–7.
86. KAY, G. M., 1941, Classification of the Artinskian series in Russia: Amer. Assoc. Petrol. Geol., Bull., vol. 25, p. 1396–1404, 4 text-fig.

87. KETYE, I. A., 1929, Correlation of Pennsylvanian-Permian of Glass mountains and Delaware mountains: *ibid.*, vol. 13, p. 904–905.
88. KING, P. B., 1949, Regional geologic map of parts of Culberson and Hudspeth counties, Texas: U. S. Geol. Survey, Oil & Gas Invest., Prelim. Map 90.
89. ——, & KING, R. E., 1928, The Pennsylvanian and Permian stratigraphy of the Glass mountains: Texas Univ. Bull., 2801, p. 142–143.
90. ——, & ——, 1929, Stratigraphy of outcropping Carboniferous and Permian rocks of Trans-Pecos Texas: Amer. Assoc. Petrol. Geol., Bull., vol. 13, p. 911, 918, 923.
91. ——, & KNIGHT, J. B., 1944, Sierra Diablo, Hudspeth and Culberson counties, Texas: U. S. Geol. Survey, Oil & Gas Invest., Prelim. Map. 2.
92. KIREEVA, G. D., 1950, Novy vidy fuzulinid iz izvestniakov C_3^1 i C_3^2 Donetzkogo basseinia: Geol. Issled. Raboty, SSSR. Glav. Uprav. Rasz, Uglya, p. 193–212.
93. KNIGHT, J. B., et al., 1940, Are the "*Omphalotrochus* beds" of the U.S.S.R. Permian?: Amer. Assoc. Petrol. Geol., Bull., vol. 24, p. 1128–1133.
94. KOCHANSKY-DEVIDE, V., 1952, Ist *Nummulostegina velebitana* Schub. identisch mit *Eoverbeckina paklenicensis* n. sp.?: Jugoslav. Akad. Znan. i. Umjet., vol. 289, p. 117–126, 2 pl.
95. ——, & RAMOVS, A., 1954, *Palaeofusulina nana* Licharew aus den Bellerophonschichten von Volska und ein Vergleich mit den Mikrofossilien anderer Fundpunkte Sloweniens: Acad. Scient. et Art, Slovenica, Classis 4, Hist. Naturalis, Dissertationes, vol. 2, p. 329–349, 1 pl.
96. KONISHI, K., 1952, Permian microfossils in the Dodo conglomerate of the Yasuba type: Paleont. Soc. Japan, Trans and Proc., n.s., no. 5, p. 155–165, pl. 14, 1 text-fig.
97. ——, 1953, New *Boultonia* and other microfossils from north Thailand (Siam): *ibid.*, no. 12, p. 103–110, pl. 11, 3 text-fig.
98. ——, 1953b, Restudy of some "*Pseudoschwagerian*" in Japan: Geol. Soc. Japan Jour., vol. 59, p. 435–436, 2 text-fig.
99. ——, 1954, Notes on the Moscovian deposits at Itoshiro-Maura, Fukui, Japan: Geol. Soc. Japan, Jour., vol. 60, p. 7–17, pl. 1.
100. LARSON, R. E., & SCOTT, J. B., 1955, *Helicoprion* from Elko county, Nevada: Jour. Paleont., vol. 29, p. 918–919. [Fusulinid evidence further extends the range of this selachian genus.]
101. LAPKIN, I. I., & KIREEVA, G. D., 1952, *Schwagerina* beds of the pre-Donetz basin: Akad. Nauk SSSR., (Doklady), vol. 82, p. 965–967.
102. LEWIS, F. E., 1941, Position of San Andres group of west Texas and New Mexico: Amer. Assoc. Petrol. Geol., Bull., vol. 25, p. 94, 97–103.
103. LICHAREW, B. K., 1934, The Permian system; on the question of its extent and stratigraphy: Prob. Soviet Geol., vol. 1, p. 161–175.
104. ——, 1940, On the occurrence of *Omphalotrochus* in the upper Carboniferous of the Donets basin: Akad. Sci., U.R.S.S., c.r. (Doklady) Moscou, n.s., vol. 27, p. 301–304. [Contains a discussion of the nomenclature of "*Schwagerina princeps*."]
105. LÖWENECK, S., 1932, Beiträge zur Kenntnis des Paläozoikums im Tianschan, (*In* Wissenschaftliche Ergebnisse der Merzbacherischen Tianschan-Expeditionen): Bayer. Akad. Wiss (Neue Folge), Heft 2.
106. MAHER, J. C., 1946, Correlation of Paleozoic rocks across Las Animas arch in Baca, Las Animas, and Otero counties, Colorado; Amer. Assoc. Petrol. Geol., Bull., vol. 30, p. 1760–1761.
107. ——, 1953, Permian and Pennsylvanian rocks of southeastern Colorado: *ibid.*, vol. 37, p. 913–939, 22 text-fig.
108. ——, 1954, Pennsylvanian correlations in Crowley and Pueblo counties, Colorado: *ibid.*, vol. 38, p. 2045–2048, 2 text-fig.
109. ——, & VOLLINS, J. B., 1953, Permian and Pennsylvanian rocks of southeastern Colorado and adjacent areas: U. S. Geol. Survey Map OM 135, Oil & Gas Invest. Ser.
110. MALDONADO-KOERDELL, M., 1952, Formaciones con fusulinidos del Permo-Carbonifero de Mexico, Ciencia (Mexico): vol. 12, p. 9–10.
111. MANUKALOVA, M. F., 1950. Opisanie nekotorykh novykh vidov fuzulinid iz srednego Karbona Donetskogo basseina: Geol. Issled. Raboty, SSSR, Glav. Uprav. Rasz. Uglya, p. 175–189, Illus.
112. ——, 1950b, Novye vidy fuzulinid iz izvestiniakov arednogo Karbona Donbassa: *ibid.*, p. 219–234, Illus.
113. MELLEN, F. F., 1947, Black Warrior basin, Alabama and Mississippi: Amer. Assoc. Petrol. Geol., Bull., vol. 31, p. 1811, 1813.
114. MIKHAILOV, A., 1939, To the characteristics of the genera of lower Carboniferous foraminifera on the territory of the USSR. The lower Carboniferous deposits of the northwestern limb of Moscow basin: Leningrad Geol. Admin., Sym. no. 3, p. 47–62. [Genotype *Fusulinella struvii* Möller.]
115. MIKLUCHO-MAKLAI, K. W., 1952, New data of the upper Paleozoic fusulinids of northern Caucasus, middle Asia and the Far East: Akad. Nauk SSSR, (Doklady), n.s., vol. 82, p. 765–767.
116. ——, 1952b, New data on upper Paleozoic fusulines from north Caucasia, central Asia and the Far East: *ibid.*, p. 989–992.
117. MIKRIUKOV, M. F., 1937, The Shikhans of Sterlitamak: Guidebook, Permian Excursion, Southern Part, 17th. Internat. Geol. Cong., p. 88, 89.
118. MINATO, M., et al., 1954, Zur Biostratigraphie der permischen Formation des Setamai-Geländes im Süd-Kitakami-Gebirge: Geol. Soc. Japan, Jour. vol. 60, no. 708, p. 378–387.

119. MOHR, C. L., 1939, Subsurface cross-section of Permian from Texas to Nebraska: Amer. Assoc. Petrol. Geol., Bull., vol. 23, p. 1698–1699, 1710.
120. MOORE, R. C., 1929, Correlation of Pennsylvanian formations of Texas and Oklahoma: *ibid.*, vol. 13, p. 898–900.
121. ——, 1940, Carboniferous-Permian boundary: *ibid.*, vol. 24, p. 282–336, 5 text-fig.
122. ——, 1949, Rocks of Permian? age in the Colorado river valley, north-central Texas: U. S. Geol. Survey, Oil & Gas Invest., Prelim. map. 80.
123. ——, 1954, Evolution of late Paleozoic invertebrates in response to major oscillations of shallow seas: Mus. Comp. Zool., Bull., Harvard College, vol. 102, p. 259–286, 15 text-fig.
124. ——, & ELIAS, M. K., 1935, Paleontologic evidences bearing on correlation of late Paleozoic rocks of Europe and North America: Cong. Strat. Carb. Heerlen 1935, c. r. vol. 2, p. 677–681.
125. ——, et al., 1951, The Kansas rock column: Kans. Geol. Survey, Bull. 89, p. 1–132, Illus.
126. MORIKAWA, R., 1949, New studying method for fusulinids: Min. Geol., vol. 3, no. 3, 2 p.
127. ——, 1950, On the genus *Nagatoella:* Geol. Soc. Japan, Jour., vol. 56, no. 657, 1 p.
128. ——, 1952, Some *Schwagerina*-like *Parafusulina:* Saitama Univ., Sci. Repts. Urawa, ser. B, vol. 1, p. 29–34, 1 pl., 1 text-fig.
129. ——, 1952b, On the new genus *Fujimotoella: ibid.*, p. 35–38, 1 pl., 1 table.
130. ——, 1952c, A method of observation for fusulinids by "sump-figures": Japanese Jour. Geol., vol. 59, p. 59–63, 8 text-fig.
131. ——, 1952d, Fusulinidae from Kanokurasawa and Sakamoto-sawa, Kitakami mountainland: Geol. Soc. Japan, Jour., vol. 58, p. 312.
132. ——, 1953, Fusulinids from the Kitakami mountainous land: *ibid.*, vol. 59, p. 149–159, 3 text-fig.
133. ——, 1953, *Triticites* limestone found in Okuchichibu: Saitama Univ. Sci. Repts. ser. B, vol. 1, p. 115–122, pl. 4, 17 tables, 1 map.
134. ——, & KAWADA, S., 1953c, Fusulinidae from the Maemonkura valley, west of Chichibu mine: Chichibu Mus. Nat. Hist., Bull., no. 3, p. 61–64, 2 text-fig.
135. MORITA, H., 1952, *Fusulina* limestone from the vicinity of Nojiri Machi, Kiso province: Geol. Soc. Japan, Jour., vol. 58, p. 443, 1 text-fig.
136. MURCHISON, R. I., 1841, First sketch of some of the principal results of a second geological survey of Russia: Philos. Mag., ser. 3, vol. 19, p. 417–422. [Publication of the letter Murchison wrote to Fischer de Waldheim proposing the Permian system.]
137. MYERS, D. A., STAFFORD, P. T., & BURNSIDE, R. J., 1956, Geology of the late Paleozoic horseshoe atoll in west Texas: Univ. Texas Publ. 5607, p. 27–29, 37–49, pl. 15–18.
138. MCNAIR, A. H., 1951, Paleozoic stratigraphy of part of northwestern Arizona: Amer. Assoc. Petrol. Geol., Bull., vol. 35, p. 521, 522, 525.
139. NALIVKIN, D. V., 1938, Scientific results of the Permian conference: Prob. Soviet Geol., vol. 7, p. 599 (*See* translation by J. S. Williams, A.A.P.G., Bull, vol. 22, p. 774–779).
140. NEWELL, N. D., 1940, Invertebrate faunas of the late Permian Whitehorse sandstone: Geol. Soc. Amer., Bull., vol. 51, p. 271–275, text-fig. 2.
141. ——, et al., The Permian reef complex of the Gaudalupe mountains region, Texas and New Mexico, a study in Paleoecology, p. 1–236, pl. 1–32, 85 text-fig., Freeman and Company, San Francisco. [A complete paleoecologic study of the Permian strata in this region. Great deal of fusulinid information utilized.]
142. ——, CHRONIC, J., & ROBERTS, T. G., 1953, Upper Paleozoic of Peru, Pt. 3 Fusulinidae: Geol. Soc. Amer., Mem. 58, p. 167–226, pl. 36–43.
143. NIKITIN, M., 1890, Note sur le calcaire Carbonifère du bassin de Moscou: Bull. Com. Géol., vol. 9, p. 27–40.
144. OWEN, D. D., 1852, On the occurrence of *Fusulina cylindrica:* Acad. Nat. Sci. Philadelphia, Proc., vol. 6, p. 118.
145. OZAKI, H., 1953, On the mode of occurrence of fossil Fusulinidae at Kinsyozan, Akasakamati, Gifu prefecture, Japan: Tokyo Nat. Sci. Mus., vol. 20, p. 8–10. [Concludes that the fusulinid *Yabeina* from limestones in the Kinsyozan region, Honshu, Japan, represents a littoral form.]
146. PEDERSON, S. L., 1954, A Permian (Wolfcampian) fauna of the Casper formation of southeastern Wyoming: Jour. Paleont., vol. 28, p. 18.
147. PETRI, S., 1952, Fusulinidae do Carbonifero do rio Tapajos, Estado do Pará: Soc. Bras. de Geol., São Paulo, vol. 1, p. 30–45, 2 pl.
148. PLUMLEY, W. J., & Graves, R. W., 1953, Virgilian reefs of the Sacramento mountains, New Mexico: Jour. Geol., vol. 61, p. 1–16, pl. 1–14, text-fig. 1–5, 2 tables.
149. PLUMMER, F. B., & MOORE, R. C., 1921, Stratigraphy of the Pennsylvanian formations of north-central Texas: Texas Univ. Bll. 2132, p. 1–237, pl. 1–27.
150. ——, & HORNBERGER, J., 1935, Geology of Palo Pinto county, Texas: *ibid.*, p. 17–65.
151. RAUSER-CHERNOUSSOVA, D. M., 1948, Lower Carboniferous endothyras of the group *Endothyra crassa* Brady and closely related forms: Akad. Nauk, SSSR., Inst. Geol. (Trudy), geol. ser., vol. 62, p. 166–175, pl. 4, 5 tables.
152. ——, 1948b, On certain endothyras of the group of *Endothyra bradyi* Mikhailov: *ibid.*, p. 176–181, pl. 5, 1 text-fig.
153. ——, 1955, Fusulinid zones and their relationship to other stratigraphic subdivisions: Moskov. Obshch. Ispytately Prirody Byull., otdel geol., tome 30, no. 4, p. 67–70.
154. ROBINSON, V., 1922, A brief geological de-

scription of the coal beds of the Carboniferous system in the Kuban region: Sovet obsledovaniya i izucheniya Kubanskov kraya (Trudy), vol. 6, fasc. 4.

155. ROTH, R. I., 1942, West Texas barred basin: Geol. Soc. Amer., Bull., vol. 53, p. 1659–1674, 2 pl., 3 text-fig.

156. ——, 1942b, Upper Pennsylvanian anhydrite, west Texas: Amer. Assoc. Petrol. Geol. Bull., vol. 26, p. 1412–1413.

157. ——, 1943, Origin of siliceous Dockum conglomerates: *ibid.*, vol. 27, p. 626, text-fig. 4.

158. ——, 1945, Permian Pease river group of Texas: Geol. Soc. Amer., Bull., vol. 56, p. 897–898, 1 text-fig.

159. ROZOVSKAIA, S. E., 1948, Classification and systematic characteristics of the genus *Triticites:* Akad. Nauk, SSSR. c. r. (Doklady), n.s., vol. 59, p. 1635–1638.

160. ——, 1949, On the problems of the evolution of the wall in the test of the Fusulinidae: Akad. Nauk, SSSR., Paleont. Inst. (Trudy), vol. 20, p. 354–358, 1 pl.

161. ——, 1951, Significance of ontophylogenetical studies in fusulinids: Moskovsk. Obsh. Ispyt. Prirod., Biull., otdel. geol., vol. 26, p. 87–88

162. ——, 1952, Fusulinidae of the upper Carboniferous and the lower Permian of the southern Urals: Akad. Nauk. SSSR., Paleont. Inst. (Trudy), vol. 40, p. 3–50, 6 pl.

163. RYNIKER, C., 1932, *Schwagerina* in the Florence Flint of Kansas (Abstract): Pan. Amer. Geol., vol. 57, p. 319.

164. SCHENCK, H. G., 1954, On the type of the genus "*Schwagerina*" von Möller 1877: Internat. Comm. Zool., Nomenclat., Opinions and Declarations Rendered, vol. 4, pt. 3, p. 29–31.

165. SEARIGHT, W. V., 1926, Global distribution of *Fusulina* (Abstract): Pan. Amer. Geol., vol. 46, p. 406.

166. SELLARDS, E. H., ADKINS, W. S., & PLUMMER, F. B., 1932, The geology of Texas: Texas Univ. Bull. 3232, vol. 1, p. 98–186, 237, pl. 5.

167. SHIKANUMA, S., 1951, *Triticites* zone at Sakamototoge, Gifu prefecture: Geol. Soc. Japan, Jour., vol. 57, p. 266.

168. SHIMIZU, S., 1896, Localities of *Fusulina* in the province of Shimotsuke: *ibid.*, vol. 3, p. 31.

169. SHROCK, R. R., & TWENHOFEL, W. H., 1953, Principles of invertebrate paleontology, 2nd Ed., McGraw-Hill Book Company, Inc., New York, p. 52–53, 60, text-fig. 2–13, 2–14.

170. SIDWELL, R., & WARN, G. F., 1953, Pennsylvanian and related sediments of upper Pecos valley New Mexico: Amer. Assoc. Petrol. Geol., Bull., vol. 37, p. 975–1013, 14 text-fig.

171. SKINNER, J. W., & WILDE, G. L., 1954, The fusulinid subfamily Boultoniinae: Jour. Paleont., vol. 28, p. 434–444, pl. 42–45. [Proposes the new subfamily Boultoniinae with the genus *Boultonia* Lee as the typical genus; also describes new genus *Paraboultonia* with *P. splendens* n. sp. as type species.]

172. ——, & ——, 1945b, Fusulinid wall structure: *ibid.*, p. 445–451, pl. 46–52. [Discusses new interpretation of the nature of the profusulinellid wall.]

173. ——, & ——, 1954c, New early Pennsylvanian fusulinids from Texas: *ibid.*, p. 796–803, pl. 95–96.

174. ——, & ——, 1955, New fusulinids from the Permian of west Texas: *ibid.*, vol. 29, p. 927–940, pl. 89–95. [Describes new genus *Paradoxiella;* first reported occurrence of *Reichelina* in the western hemisphere; also reports the occurrence of *Yabeina*, the first neoschwagerinid to be reported from west Texas.]

175. SMITH, A. J., 1899, *Fusulina cylindrica* shell structure: Kans. Acad. Sci., Trans., p. 64–65, 1 pl.

176. TAMURA, M., SATO, T., & TOYAMA, N., 1952, Discovery of *Fusulina* from the Paleozoic formations in the northern part of the Kitakami mountains: Geol. Soc. Japan, Jour., vol. 58, p. 154.

177. TEICHERT, C., 1941, Upper Paleozoic of western Australia: correlation and paleogeography: Amer. Assoc. Petrol. Geol., Bull., vol. 25, p. 371–415, 6 text-fig.

178. TELLER, F., 1889, Fusulinenkalk und Uggowitzer Breccie innerhalb der Weitensteiner Eisenerz-formation und die Lagerungsbeziehungen dieser paläozoischen Gebilde zu den triadischen und tertiären Sedimenten ces Weitensteiner Gebirges: K. K., Geol. Reichs., Wien., Verh., p. 1–12.

179. THOMAS, H. D., THOMPSON, M. L., & HARRISON, J. W., 1953, Fusulinids of the Casper formation of Wyoming: Wyo. Geol. Survey, Bull. 46, p. 15–56, pl. 1–9, 4 text-fig., tables.

180. THOMPSON, M. L., 1941, Permian fusulinids from British Columbia, Washington, and Oregon (Abstract): Geol. Soc. Amer., Bull., vol. 52, p. 1984.

181. ——, 1953, Primitive *Fusulinella* from southern Missouri (A correction): Jour. Paleont., vol. 27, p. 748.

182. ——, 1954, American Wolfcampian fusulinids: Univ. Kans. Paleont. Contr., Protozoa Article 5, p. 1–226, pl. 1–52, text-fig. 1–14.

183. ——, 1954, Comments on type species of "*Schwagerina*": Internat. Comm. Zool. Nomenclat., Opinions and Declarations Rendered etc., vol. 4, pt. 3, p. 33–34.

184. ——, & Bissell, H. J., 1940, Pennsylvanian and Permian fusulinids of Wasatch mountains, Utah (Abstract): Oil & Gas Jour., vol. 38, no. 48, p. 67.

185. ——, & HAZZARD, J. C., 1940, Permian fusulinids from the Providence mountains, California (Abstract): *ibid.*

186. ——, & MELLEN, F. F., 1949, Foraminifers in the Black Warrior Basin of Mississippi and Alabama: Miss. Geol. Soc. Guidebook, 7th Field Trip, p. 44–54, pl. 4–5. [First oc-

currence of fusulinid genus *Millerella* in Black Warrior basin.]

187. ——, PITRAT, C. W., & SANDERSON, G. A., 1953, Primitive Cache Creek fusulinids from central British Columbia: Jour. Paleont., vol. 27, p. 545–552, pl. 57–58, 3 tables.
188. ——, & ZELLER, D. N., 1956, *Profusulinella* in western Utah: *Ibid.*, vol. 30, p. 333–337, pl. 34, 1 text-fig. [First *Profusulinella* to be described from western Utah.]
189. TOLSTIKHINA, M. M., 1936, Materials for the stratigraphy of the upper Paleozoic in the region of Kisel: Notes All-Russian Min. Soc., vol. 65, p. 1–40.
190. ——, 1937, Kuzino to Perm: Guidebook, Permian Excursion, Northern Part, 17th. International Geol. Congress, p. 38.
191. ——, 1937b, The Asha works: *ibid.*, Southern Part, p. 116.
192. TOOMEY, D. F., 1954, A bibliography of the family Fusulinidae: Jour. Paleont., vol. 28, p. 465–484.
193. TORIYAMA, R., 1941, Carboniferous foraminifera from the Sosan district, north Heian-do, Tyosen: Palaeont. Soc. Japan, Trans., no. 140, p. 563–567, 11 text-fig.
194. ——, 1949, Fusulinid fossils of the Gampi, Beppu, and Tsunemori groups: Geol. Soc. Japan, Jour., vol. 55, nos. 648–649, p. 125.
195. ——, 1950, On the most recent studies of the fusulinid foraminifera: Min. Geol., vol. 3, no. 6, p. 1–4, 3 text-fig.
196. ——, 1952, Permian fusulinids from the Kitakami mountainland, northeast Japan: Kyushu Univ. Fac. Sci., Mem., ser. D, vol. 3, p. 127–156, pl. 1–7, 1 table.
197. ——, 1953, Reminiscences of my studies of Foraminifera in the United States: Yukochu (Foraminifera), no. 1, p. 28–30.
198. ——, 1953b, Stratigraphy and fossil zones in the Paleozoic beds of southwestern Japan: Geol. Soc. Japan, Jour., vol. 59, p. 290–294.
199. ——, 1954, Geology of Akiyoshi. Pt. 1. Study of the Akiyoshi limestone group: Fac. Sci. Kyushu Univ., Mem., Ser. D, vol. 4, p. 39–97, 28 text-fig., 1 map.
200. ——, 1954b, Geology of Akiyoshi. Pt. II. Stratigraphy of the non-calcareous groups developed around the Akiyoshi limestone group: *ibid.*, vol. 5, p. 1–46, 6 text-fig., 5 tables.
201. ——, 1954c, A gigantic fusulinid species from the Kitakami massif, northeastern Japan: Paleont. Soc. Japan, n.s., no. 15, p. 179–182, pl. 24, 2 text-fig.
202. TRÜMPY, D., 1943, Pre-Cretaceous of Columbia: Geol. Soc. Amer., Bull., vol. 54, p. 1281–1304.
203. TUMANSKAYA, O. G., 1952, Representatives of the genera *Pseudodoliolina* and *Polydiexodina* in the Permian of SSSR.: Moskovsk. Obsh. Ispytat. Prirod. Biull., Otdel. geol., vol. 27, p. 68–72.
204. VISSARIONOVA, A. I., 1948, The group of *Endothyra globulus* from the Visean stage of the lower Carboniferous in the European part of the Union: Akad. Nauk, SSSR., Inst. Geol. (Trudy), geol. ser., vol. 62, p. 182–185, pl. 6.
205. ——, 1948b, Primitive fusulinids from the lower Carboniferous of the European part of the Union: *ibid.*, p. 216–226, pl. 13–14.
206. WANLESS, H. R., 1955, Pennsylvanian rocks of Eastern Interior basin: Amer. Assoc. Petrol. Geol., Bull., vol. 39, p. 1753–1820, 16 text-fig.
207. ——, BELKNAP, R. L., & FOSTER, H., 1955b, Paleozoic and Mesozoic rocks of Gros Ventre, Teton, Hoback, and Snake river ranges, Wyoming: Geol. Soc. Amer., Mem. 63, p. 31–36.
208. WENGERD, S. A., & STRICKLAND, J. W., 1954, Pennsylvanian stratigraphy of Paradox Salt basin Four Corners region, Colorado and Utah: Amer. Assoc. Petrol. Geol., Bull., vol. 38, p. 2157–2199, 14 text-fig.
209. WHITE, M. P., 1932, Fusulinid sports (Abstract): Pan. Amer. Geol., vol. 57, p. 320.
210. YABE, H., 1935, Carboniferous-Permian deposits of the Japanese islands, Tyosen and Manchuria: Cong. Strat. Carb. Heerlen 1935, c. r., vol. 3, p. 1617–1649.
211. ——, 1940, Paleozoic formations of Japanese islands: Proc. 6th. Pacific Science Congress 1939, vol. 1, Univ. California Press, California, p. 377–392.
212. ——, & HAYASAKA, I., 1920, Paleontology of southern China, (*In* Geographical Research in China): Tokyo Geog. Soc. vol. 3.
213. YAMAGIWA, N., 1954, New localities of fusulinids and tetracorals from the northern part of Settu province: Geol. Soc. Japan, Jour., vol. 60, no. 707, p. 356.
214. YEN, T. P., SHENG, C. C., & KENG, W. P., 1951, The discovery of fusuline limestone in the metamorphic complex of Taiwan: Geol. Surv. Taiwan, Bull. B, no. 3, p. 35–44, 1 text-fig.
215. ——, ——, & ——, 1951b, On the occurrence of the late Paleozoic fossils in the metamorphic complex of Taiwan: *ibid.*, no. 4, p. 23–26.
216. YOKOYAMA, T., 1954, The Permian system of the Taishaku region, Hiroshima prefecture: Geol. Soc. Japan, Jour., vol. 60, no. 706, p. 302.
217. YOSHIMURA, N., 1954, The Permian system in the Takayamason area, Okayama prefecture: *ibid.*
218. YOUNGQUIST, W., & HAEGELE, J. R., 1955, Fusulinid bearing rocks in the Sublett range, southern Idaho: Amer. Assoc. Petrol. Geol., Bull., vol. 39, p. 2078–2090, 4 text-fig.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1367–1375, 3 TEXT-FIG., NOVEMBER 1956

PALEONTOLOGICAL NOTES

THE MISSISSIPPIAN NAUTILOID GENUS *TYLODISCOCERAS* IN KENTUCKY AND TENNESSEE

CHARLES W. COLLINSON
Illinois State Geological Survey, Urbana*

Miller & Collinson in 1950 described a large, nodose, discoidal nautiloid from south-central Kentucky and coined for it the name *Tylodiscoceras unicum*. The specimen was discovered in residual soil from the Warsaw and St. Louis formations. It was concluded, therefore, that it probably was Meramecian in age but that it could, of course, have been let down vertically.

In 1954, at my request, Edmund Nosow, of the Kentucky Geological Survey, and Prentice Lawrence, who in 1946 had discovered the holotype of *T. unicum*, examined the area where the specimen was found. Of the fossil locality, Nosow wrote:

> It is exactly 3 miles north of the Kentucky-Tennessee line and .85 mile east of the west edge of the Dot, Ky.-Tenn. quadrangle. From the chert scattered about, the area appears to be underlain by St. Louis limestone. However, along the road going north, just west of the fossil site, I found a large fragment of porous oolitic chert which we would normally place in the Ste. Genevieve. Conceivably, the fossil could have weathered from the Fredonia, and certainly not lower than the uppermost St. Louis.

In November, 1954, Fred Williams of the Aluminum Company of America at Rosiclare, Illinois, sent me a second representative of the species, which had been collected by Otto Cochran of the same firm. The specimen was found among chert float eight-tenths of a mile northeast of Lola, Livingston County, Kentucky, near the east bank of Deer Creek (some 80 miles west-northwest of the locality that yielded the holotype). It was found within 500 feet of a gravel road that leads northeast from Lola. The area is mapped as underlain by the Fredonia member of the Ste. Genevieve formation (Weller & Sutton, 1951) and no rocks of St. Louis or Warsaw age are mapped in the upstream drainage of Deer Creek. However, when I visited the collecting locality I found residual chert, like that in which the specimen is preserved, very abundant on the surface, much of it relatively fresh. Several outcrops of dense, dark gray limestone and one of dark gray oolite were found. These facts, when considered together, seem to indicate that the rocks underlying the area are of St. Louis age rather than Ste. Genevieve, and the specimen is therefore assumed to be from the St. Louis.

The specimen closely resembles the holotype both in size and preservation, although it is slightly distorted. It is preserved in chert and chalcedony and is incomplete adorally. The maximum overall dimension is 24 cm., but, when complete, the specimen must have exceeded 26 cm. in diameter. All but the adoral quarter-volution is septate. A natural longitudinal section of the mature portion of the conch shows many of the septa to be broken and scattered within the conch. The test is preserved, and the growth lines are the only feature exhibited by the hypotype that are not as well preserved on the holotype. These are directly transverse on the umbilical walls and dorsolateral zones of the conch, but they curve apicad on the ventrolateral zones. They cross the ventral keels at an angle of approximately 45° and form relatively shallow, narrowly rounded sinuses on the venter.

A third representative of *Tylodiscoceras* was sent to me by Nosow in November 1954, and it represents a new species of the genus. The specimen was found by Knox Thomas whose address is R. R. #1, Guthrie, Kentucky, but who actually lives in Tennessee.

The new specimen (Text-fig. 1) is designated the holotype of a new species named in honor of Nosow, who spent much time and effort in securing the specimen and gathering data about it. Of the holotype Mr. Nosow wrote:

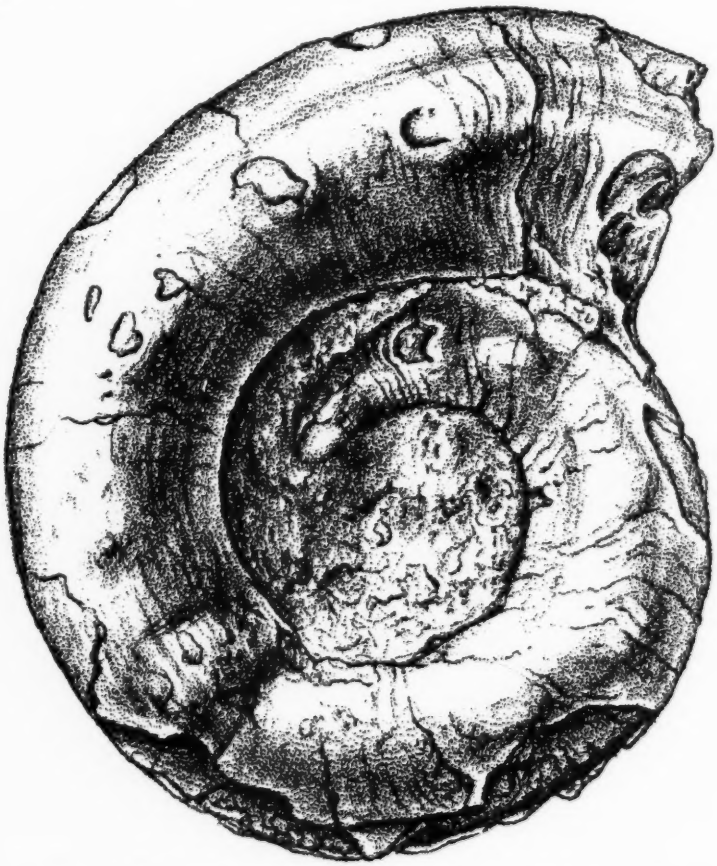
* Published with the permission of the Chief.

This third *Tylodiscoceras* was found in Montgomery County, Tennessee, approximately 2.7 air miles southwest of Guthrie (Todd County, Ky.), and 0.4 mile south of the Kentucky-Tennessee line. It was found in a field just north of the sharp bend in Spring Creek (see Guthrie Ky.-Tenn. quadrangle). There were numerous weathered chert fragments scattered about in the same field, the nearest limestone outcrop being along the bank of Spring Creek. The limestone is medium-gray in color, crystalline, slightly dolomitic, very fossiliferous, and contains many small fossil fragments that give the rock a semi-oolitic appearance. The limestone contains large nodular fragments of unweathered translucent bluish chert. The weathered chert strewn about the field has a reddish-brown appearance, but when broken the fresh surface discloses a creamy-white color; the chert is very porous, and abundantly fossiliferous. Most of the fossils are fenestellids or brachiopods and the chert looks like the Lost River Chert which marks the St. Louis-Ste. Genevieve contact. The specimen of *Tylodiscoceras* probably weathered out of basal Ste. Genevieve limestone at this locality.

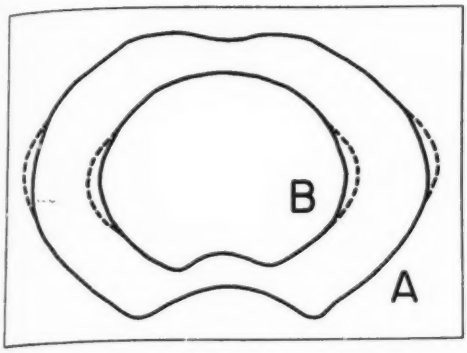
TYLODISCOCERAS NOSOWI Collinson, n.sp.
Text-fig. 1,2

This species is based on a single, large, well-preserved specimen that, like the other two known representatives of the genus, is largely silicified. Although the specimen is not complete adorally, it has a maximum over-all diameter of 30 cm., and the adoral quarter-volution appears to have been living chamber.

The conch (Text-fig. 1) consists of at least three volutions, is discoidal in shape, and is slightly impressed dorsally. It is nautiloconic in its mode of growth and is depressed in cross section. Where the speci-



TEXT-FIG. *1—Tylodiscoceras nosowi* Collinson, n. sp. Lateral view of the holotype from either the upper St. Louis or the lower Ste. Genevieve limestone in Montgomery County, Tennessee, 2.7 miles southwest of Guthrie, Todd County, Kentucky, ×⅔.



TEXT-FIG. 2—*Tylodiscoceras nosowi* Collinson, n. sp. Outline cross sections of the conch. Dotted lines represent adjacent nodes. *A*, was taken at an overall diameter of 250 mm.; *B*, at an overall diameter of 145 mm. Both ×⅔.

men is 250 mm. in diameter, the conch is 93 mm. high and 130 mm. wide (not including nodes). At a diameter of 145 mm. the conch is 65 mm. high and 81 mm. wide. The lateral zones of the conch are rounded, and the venter is broadly rounded except in the last volution, which possesses a ventral concave zone (Text-fig. 2). The concave zone first appeared where the conch is 140 mm. high, and it increased in width to about 40 mm. at what is now the adoral end of the specimen. The borders of the zone appear to have been rather indefinite but the specimen has been crushed and distorted in such a fashion as to greatly accentuate them. On the ventrolateral zones of the conch there are shallow furrows, which are well shown in Text-fig. 1. These furrows appear to be a rudimentary form of ornamentation distinct from the nodes or ventral concave zone. On each of the lateral zones there is a single row of nodes that are very distinct on the immature portions of the conch but become less so in the outermost volution. Where prominent, the nodes are all of like shape and spacing, and there are about five nodes per quarter volution. In the outermost volution the nodes are irregularly spaced.

The umbilicus is large and open; its width is equal to about half the diameter of the specimen. The umbilical shoulders are smooth and rounded, and the umbilical walls are steep and relatively straight. Although it is not completely exposed, the umbilicus appears to be perforate.

The thick test is well preserved. It averages about five mm. thick and is slightly thinner on the dorsolateral zones of the conch than elsewhere. The surface of the specimen is well marked by growth lines that form broad, shallow, narrowly rounded hyponomic sinuses and very broad, very shallow, ventrolateral salients. On the umbilical wall they are essentially straight and transverse.

There are about four and one-half camarae in the most apicad quarter of the outer volution. Although the camarae are not well exposed, it appears that the adoral ones are shorter than those preceding them. Such shortened camarae usually are interpreted as representing late maturity in an individual. The sutures also are poorly exposed, but they appear to form broad ventral lobes, shallow broadly rounded lateral saddles, and shallow broadly rounded umbilical saddles that center near the umbilical seam. The nature and position of the siphuncle are not revealed.

Remarks.—Although this species is based on only a single individual, it seems so distinct from *T. unicum*, the only other known representative of the genus, that there is little possibility of its being a variant of the genotype. *T. nosowi* differs from *T. unicum* mainly in that the ventral depressed zone is much less distinct and is developed only on the mature portion of the conch. Furthermore, the nodes on the mature portion of *T. nosowi* are less distinct and less regular in spacing and shape than in the genotype.

T. nosowi has many characteristics that seem to indicate it is related to *Endolobus*, but its ventral depressed zone indicates its position in the genus *Tylodiscoceras*. However, the fact that the ventral depressed zone is developed only on the mature part of the conch may be taken to indicate that *T. nosowi* is more primitive than the genotype and that *Tylodiscoceras* arose from *Endolobus*.

REFERENCES

MILLER, A. K., & COLLINSON, CHARLES, 1950, A unique Mississippian nautiloid from Kentucky: Jour. Paleont., vol. 24, p. 673–674.

WELLER, STUART, & SUTTON, A. H., 1951, Geologic map of the western Kentucky fluorspar district: U. S. Geol. Surv. Mineral Inv. field studies map MF-2.

OCCURRENCE OF *SPINAPTYCHUS* IN TEXAS

JOHN T. TWINING
Bureau of Economic Geology, The University of Texas, Austin*

In June 1953, W. S. Adkins and the writer collected fragments of ammonoid operacula from the Upper Cretaceous Terlingua clay of west Texas. The identity of these specimens was not recognized until H. B. Stenzel called attention to a publication by Fischer & Fay (1953) in which these authors recorded the first occurrence of the genus *Spinaptychus* Trauth, in North America and described the new species *S. sternbergi* from the Smoky Hill chalk member, Niobrara formation, Colorado group, Upper Cretaceous, of Gove and Logan counties, Kansas.

All the specimens collected from the Terlingua clay are fragments, but the preservation is good and details of the morphological features, with the exception of the over-all outline and size of the valves, are clearly defined. The outer surfaces bear irregularly distributed, pitted tubercles and scattered, unpitted, smaller tubercles and pustules. The inner surfaces are marked by distinct growth lamellae which result from the imbricate, laminar shell structure. The harmonic margins bear a concavo-convex flange which gradually widens towards the ventral margin. The larger fragments are all parts of the harmonic margins, the thickest part of the valve, and show this margin to be nearly straight. The thickness of the shell (up to three mm. on the largest fragment) and the size of the harmonic flange on the fragments from mature parts of valves indicate that the Texas valves are fully as large as those described from Kansas. The Texas specimens certainly appear to be conspecific with *Spinaptychus sternbergi* Fischer & Fay (1953).

Specimens have been collected from the three following separate localities in the Terlingua clay, all in the Study Butte-Terlingua area of southwestern Brewster County, Texas:

1. Base of low clay hill on southwest side of Maverick Mountain, half a mile east of Study Butte.
2. Clay slopes on northwest side of small igneous peak, half a mile east of Bee Mountain and one mile north of Study Butte.
3. Clay flats southwest of Cuesta Blanca, three miles east-southeast of Terlingua and three and one half miles west-southwest of Study Butte.

At all three localities the aptychi are associated with a varied, apparently dwarfed, fauna consisting of corals, pelecypods, gastropods, nautiloids, and ammonites. This fauna has not been studied, and there is some doubt as to the exact age of the Terlingua clay. It is known that the ammonite-bearing chalks and marls underlying the clay are equivalent to some part of the Austin group (Coniacian-Santonian) of the central Texas section, and that the lower part at least of the overlying Aguja formation is in part equivalent to the Taylor formation (Campanian). The Terlingua clay has generally been accepted as representing beds of Taylor equivalency in west Texas (Adkins, 1933, and Stephenson et al., 1942), but recent field work in Brewster County indicates that the lower part, if not all, of the formation represents beds which correlate with the upper part (Santonian) of the Austin group (Maxwell et al., 1955, p. 37-39, tables 3, 4; and Hazzard et al., 1956, p. 45,111–119). If the latter correlation is correct, then both the Kansas and Texas specimens of *Spinaptychus sternbergi* are of the same age (i.e., Santonian).

At all three localities the fauna associated with the aptychus fragments contain ammonites but, with one exception, all are small and could not have reached diameters in excess of 50 to 60 mm. The aptychi are much too large to have served as opercula for any of these ammonites. The one exception is a poorly preserved internal mold of the outer whorl of a large *Texanites* sp. found in a small chalk lentil at Locality 2. Aptychi were not found in the chalk lentil but two large fragments are covered with a chalky matrix and may have weathered out of the chalk. Other fragments were collected from the clays surrounding the lentil. Although not in direct association, this *Texanites*

* Publication authorized by the Director.

specimen is the only ammonite seen at any of the three localities that is large enough to have produced these aptychi. This evidence is considered as strong support in favor of the probable affinity of *Spinaptychus* to *Texanites* as stated by Cox (1926) and Fischer & Fay (1953).

REFERENCES

Adkins, W. S., 1933, The Mesozoic systems in Texas, *in* The geology of Texas: Univ. Texas Bull. 3232, 1932, p. 239–518.

Cox, L. R., 1926, *Aptychus spinosus*, sp. n., from the upper Chalk: Ann. Mag. Nat. Hist., London, ser. 9, vol. 17, p. 574–580.

Fischer, A. G., & Fay, R. O., 1953, A spiny aptychus from the Cretaceous of Kansas: Kans. Geol. Surv. Bull. 102, p. 77–92, pl. 1,2.

Hazzard, R. T., Sullins, M. J., Dodson, J. I., & Allor, R. H., 1956, Notes on stratigraphic sections of the Anacacho Mountains: San Angelo Geol. Soc. Guidebook, Four Provinces Field Trip, p. 45,46,111–131.

Maxwell, R. A., Lonsdale, J. T., Hazzard, R. T., & Wilson, J. A., 1955, The Big Bend region; Cretaceous rocks: West Texas Geol. Soc. Guidebook, 1955 Spring Field Trip, p. 25–41.

Stephenson, L. W., King, P. B., Monroe, W. H., & Imlay, R. W., 1942, Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas: Geol. Soc. Amer. Bull., vol. 53, p. 435–448, 1 pl.

A NEW DEVONIAN CHAROPHYTE

GEORGE B. CHOQUETTE

Honolulu Oil Corporation, Calgary

INTRODUCTION

A study of charophyte gyrogonites from the Middle Devonian Elk Point group reveals the presence of a species with sinistrally spiralled ridges here named *Eochara wickendeni* Choquette.

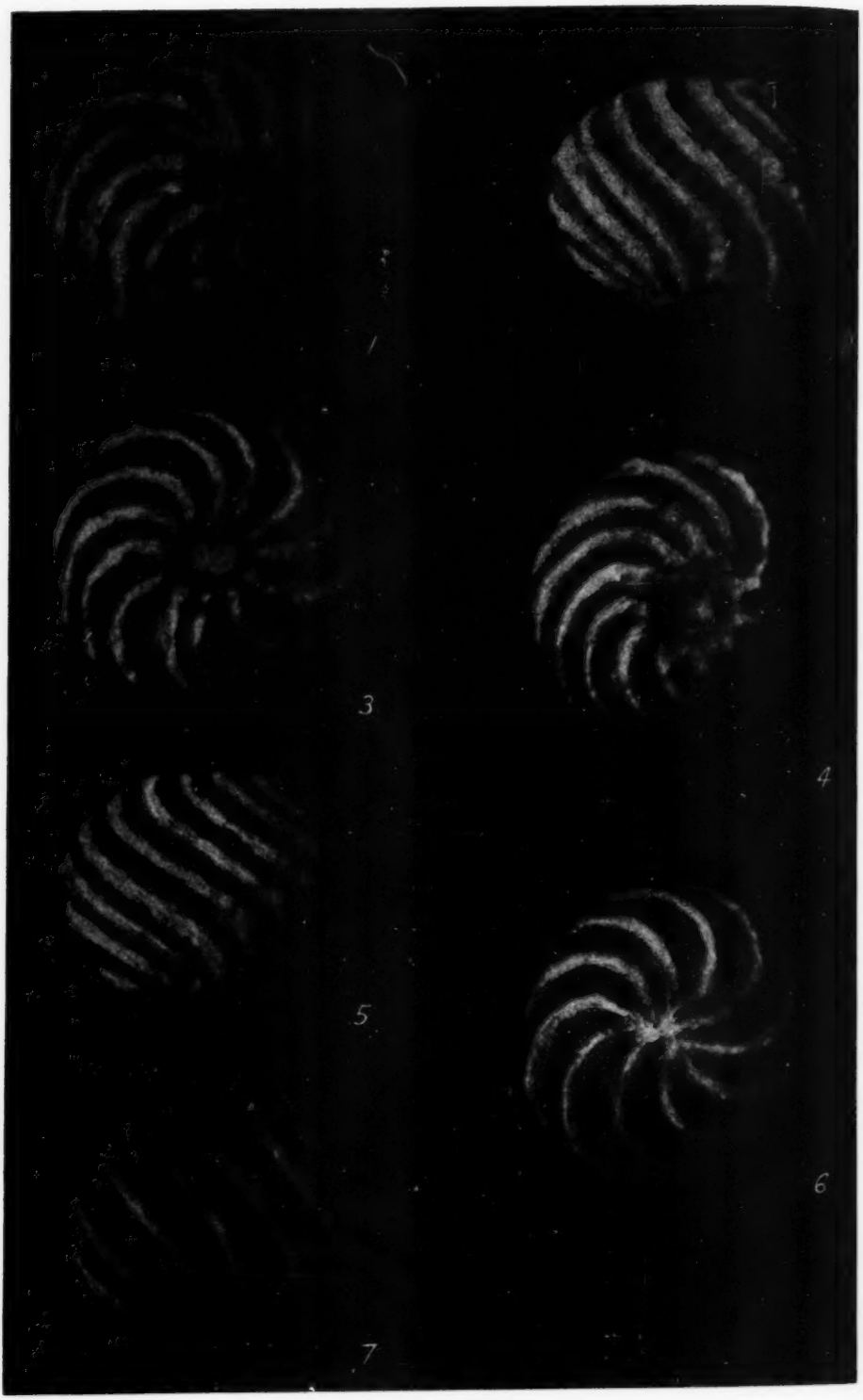
The Elk Point group is a dominantly evaporitic sequence in the Canadian Plains region. It was originally described by McGehee (1949) as a formation of Silurian age except for some possible Devonian beds at the top. Later (1952) he considered it all as Middle Devonian age. Belyea (1952) raised the Elk Point to group rank and pointed out several lithologic units without naming them. The Elk Point unconformably overlies Silurian, Ordovician, Cambrian, and Pre-Cambrian strata, and is conformably overlain by the Beaverhill Lake formation. The lithology varies considerably; there is much salt, anhydrite, dolomite, limestone and shale, and minor amounts of siltstone and sandstone. Colors range through buff, red, brown, green, and gray. The group shows cycles of evaporitic deposition followed by normal marine deposition.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the valuable help and encouragement so freely given by Dr. R. T. D. Wickenden of the Geological Survey of Canada, Professor R. E. Peck of the University of Missouri, Mr. L. E. Workman of Canadian Stratigraphic Service Limited, and Dr. G. O. Raasch of Shell Oil Company. The photographic illustrations were prepared by Professor M. G. Mehl of the University of Missouri.

OCCURRENCE AND SIGNIFICANCE

Charophyta occur in three zones in the Elk Point group: the most persistent zone is near the top; another less persistent is below the "first salt," or equivalent strata, and the third occurs sporadically below the "second salt." The upper and lower limits of these zones are not sharply delineated and the fossils are not confined to specific lithology. However, thin beds of green fine-textured shale and beds of evaporitic dolomite and limestones are the types of rock in which the fossils are most frequently found. The zones vary from a few inches to as much as 200 feet in thickness, the average thickness being 10 to 30 feet with a peak of fossil abundance within the zones. At present there is no evidence to show that each of the zones is characterized by any particular species. However, it is thought that the three zones form continuous links of deposition between the different lithological units, and



TEXT-FIG. 1

that the charophytes themselves will assist in the closer determination of the ages of the formations in the group. Associated fossils are *Styliolinas*, ostracods, brachiopods, crinoids, and *Tentaculites*.

The charophytes from the Elk Point group thus far revealed are of two types: those which are vertically ridged; and those which have sinistrally spiralled ridges. This paper concerns the latter.

In 1886 Ulrich described a collection of small fossils from the Devonian at the Falls of the Ohio under the name of *Moellerina greenei*. Although these forms were referred to the Foraminifera by Ulrich, there is little doubt but that they represented gyrogonites of Charophyta. Later Knowlton (1889) suggested that *Moellerina* belonged to the Charophyta. Ulrich's description does not state the direction of the spirals on *Moellerina greenei*, but his illustrations indicate that the spirals ascended sinistrally. Additional collecting at the Falls of the Ohio has failed to yield sinistrally spiralled gyrogonites, but the dextrally spiralled forms are common there. This fact led Peck (1934) to conclude that Ulrich's illustrations of *Moellerina greenei* had been reversed in reproduction and that Ulrich had probably studied dextrally spiralled forms. The types of *Moellerina greenei* have been lost, and there is no way to determine whether the name applies to sinistrally or dextrally spiralled gyrogonites. Quenstedt (1885) also illustrated a sinistrally spiralled fossil which was judged to have been incorrectly drawn.

The oldest properly recorded sinistrally spiralled charophyte gyrogonites have been described by Bell (1922) as *Paleochara acadica* from the Pennsylvanian of Nova Scotia. This species contains six or more sinistral spirals.

Because of the uncertainty of Ulrich's forms, and because *Moellerina* was described as a Foraminifera, it is considered best to describe the sinistrally spiralled gyrogonites from the Devonian of Canada under a new generic name, *Eochara*. *Eochara* differs from *Paleochara* Bell in possessing more than six sinistrally spiralled ridges.

SYSTEMATIC DESCRIPTION

Genus EOCHARA Choquette, n. gen.

Type species.—*Eochara wickendeni* Choquette, n. sp.

Diagnosis.—Gyrogonites composed of more than six sinistrally spiralled units. Vegetative parts unknown.

EOCHARA WICKENDENI Choquette, n. sp.
Text-fig. 1—1–7

Description.—Small slightly ellipsoid to subspherical gyrogonites with 8 to 13 sinistrally spiralled units ranging from .3 mm. to .6 mm. in diameter. The average of 20 specimens measured is .467 mm. Spirals consist of sharp and prominent intercellular ridges separated by deep concave cellular furrows. The spirals complete about one turn in their ascent and cross the equator of the specimens at an angle of approximately 30°. Summit opening fairly large. Most specimens have a small boss at base which protrudes slightly from the basal end, the boss slightly concave on some specimens.

Types.—Holotype: 6633, Geol. Mus. Canada; paratypes: 6634 and 6635, Geol. Survey Canada.

Occurrence.—Barnsdall, West Wabiskaw #1 Well, Lsd. 11, Sec. 17, T. 78, R. 2, West of the Fifth Meridian, Alberta, Canada. Depth: 5130–5135 feet. (11 & 12 spiral), 5190–5200 feet (10 spiral). Elk Point group (Middle Devonian).

CONCLUSIONS

In his comprehensive work on the Trochilisks, Peck (1934) considered the number of spiral ridges on the dextrally spiralled representative of *Trochiliscus* a specific character of major importance. Croft (1952) discusses

TEXT-FIG. *1*—*Eochara wickendeni* Choquette, n. sp. Figures are ×84

1—Superior view of holotype, 12 intercellular ridges. Nat. Mus. Canada, Cat. No. 6633.
2—Lateral view, same specimen.
3—Inferior view, same specimen.
4—Superior view of paratype, 11. intercellular ridges. Nat. Mus. Canada, Cat. No. 6634.
5—Lateral view, same specimen
6—Inferior view of paratype, 10 intercellular ridges. Nat. Mus. Canada, Cat. No. 6635.
7—Lateral view, same specimen.

at some length the characters that are of specific value in *Trochiliscus* and concludes that form, size, and general configuration should be given more weight than number of spirals. Croft believed that a single plant of the genus *Trochiliscus* probably bore oogonia with different numbers of spiral enveloping cells. Peck (personal communication) agrees with the general thesis of Croft, and advises that he believes that all of the known specimens of *Eochara* with spirals ranging from 8 to 13, should be referred to a single species.

REFERENCES

BELL, W. A., 1922, A new genus of Characeae and new Manostomata from the Coal Measures of Nova Scotia: Roy. Soc. Can., Proc. & Trans., 3rd ser., vol. 16, p. 159–167.

BELYEA, HELEN R., 1952, Notes on the Devonian system of the north-central plains of Alberta: Can. Dept. of Mines & Tech. Surv., Paper 52-27, Ottawa.

CROFT, W. N., 1952, A new Trochiliscus (Charophyta) from the Downtonian of Podolia: Brit. Mus. (Nat. Hist.), Bull. Geol., vol. 1, no. 7, p. 189–220, pl. 18–19.

HORN AF RANTZIEN, H., 1956, An annotated check-list of genera of fossil Charophyta: Micropaleont., vol. 2, no. 3, p. 243–256.

KNOWLTON, F. H., 1889, Description of a problematic organism from the Devonian at the Falls of the Ohio: Amer. Jour. Sci., 3rd ser., vol. 37, p. 202–209.

MCGEHEE, J. R., 1949, Pre-Waterways paleozoic stratigraphy of Alberta plains: Amer. Assoc. Petrol. Geol. Bull., vol. 33, no. 4, p. 603–613.

——, 1952, A resume of the Elk Point formation in view of recent drilling in the Williston Basin: Billings Geol., Soc. Guide Book, 3rd Ann. Field Conf., p. 64.

PECK, R. E., 1934, North American Trochiliscids, Paleozoic Charophyta: Jour. of Paleont., vol. 8, p. 83–119.

QUENSTEDT, FR. AUG., 1885, Handbuch der Petrefaktenkunde: 3 Aufl., p. 1083.

ULRICH, E. O., 1886, Descriptions of new Silurian and Devonian Fossils: Contr. to Amer. Paleont., Cincinnati, vol. 1, p. 3–35, pl. 1–3.

WEBB, J. B., 1951, Geological history of the plains of western Canada: Amer. Assoc. Petrol. Geol., Bull., vol. 35, no. 11, p. 2291–2315.

SWARTZOCHILINA, NEW GENUS OF ISOCHILINID OSTRACODE

HAROLD W. SCOTT
University of Illinois, Urbana

In 1937 Teichert described the genus *Dihogmochilina* to include "Leperditiidae that are similar to *Isochilina*, but have a forked sulcus behind the eye-spot. The muscle-spot is located between the two forks of the sulcus." *Isochilina grandis* var. *latimarginata* Jones, was designated type species.

Swartz, 1949 (p. 325–326, pl. 66, fig. 14–16), described a new species as *Dihogmochilina straitcreekensis* and redefined the genus on the basis of this species. However, it appears that *D. straitcreekensis* is sufficiently different from the type species of *Dihogmochilina* to warrant generic separation, and consequently a new genus is proposed.

SYSTEMATIC DESCRIPTION

Genus SWARTZOCHILINA Scott, n. gen.

Type species.—*Dihogmochilina straitcreekensis* Swartz, 1949.

Diagnosis.—Swartz's description of *Dihogmochilina* is applicable to this genus, and reads as follows:

> Isochilininae with well-developed borders along the free margins of the valve; surface strongly sculptured, the adductor scar clearly reflected exteriorly; above the position of the adductor scar, the surface is creased by a shallow furrow . . . narrow flanges bend abruptly downward from the outer edge of the marginal border of both valves, the flanges probably overlapping when the valves were closed; submarginal right valve pits and corresponding internal nodes, such as occur in *Isochilina ottawa*, are absent here; there is a strongly developed chevron ridge below the eye tubercle.

Swartzochilina as thus defined differs from *Dihogmochilina* in the strong sculpturing of the surface, pronounced eye tubercle, deep and elongate sulcus that reaches below the eye-spot, strong chevron-ridge, and two or more deep rounded pits antero-dorsal to eye-tubercle. *Swartzochilina* lacks the submarginal pits in the right valve as found in *Isochilina*.

REFERENCES

SWARTZ, F. M., 1949, Muscle marks, hinge and overlap features, and classification of some Leperditiidae: Jour. Paleont. vol. 23, no. 3, p. 306–327, pl. 65–67.

TEICHERT, C., 1937, Ordovician and Silurian faunas from Arctic Canada: Copenhagen Univ. Min. Geognost. Mus. Comm. Paleont. No. 59, p. 105–122,150–155, pl. 22–24.

THE TRACHYPSAMMIACEA, PERMIAN OCTOCORALLIA

FREDERICK M. BAYER
U. S. National Museum

In the July 1956 issue of the JOURNAL OF PALEONTOLOGY, Professor Eugenia Montanaro Gallitelli proposed a new order, Trachypsammacea [*sic*] for Gerth's *Trachypsammia*. However, she had previously given nomenclatural status to this ordinal taxon in a short paper published in Italy (1955). She had also prepared, at my request, the discussion of *Trachypsammia* that appeared in the section on the Octocorallia in the Treatise on Invertebrate Paleontology. In that discussion, also, the ordinal name was indicated to be new. I was unaware of the Italian publication at the time I read the Treatise proof, because that number of the Atti e Memorie did not reach Washington until April 1956. Montanaro Gallitelli knew of the paper but had no opportunity to read the proof of her paper in the Journal.

REFERENCES

MONTANARO GALLITELLI, EUGENIA, 1955, Trachpsammacea [sic] un nuovo ordine dei Celenterati: Modena Accad. Sci. Lettere e Arti, Atti e Memorie, ser. 5, vol. 13, p. 224–226 (published December 27).

——, 1956, *Khmeria* and *Trachypsammia* from the Permian of Sosio, Sicily: Jour. Paleont., vol. 30, p. 876–882, pl. 99, 100 (published August 31).

——, 1956, Trachypsammiacea, *in* Anthozoa, Octocorallia by F. M. Bayer: Treatise on Invertebrate Paleontology (R. C. Moore, Dir. & Ed.), Coelenterata, p. F190–F192 (published September 21).

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1376–1381, NOVEMBER 1956

REVIEWS

JURASSIC GEOLOGY OF THE WORLD, by W. J. Arkell. Oliver and Boyd, Ltd., 806 p., 46 pl., 102 Text-fig., 28 correlation tables. 1956. Price $16.50.

The almost impossible task of preparing an orderly and thorough synthesis of existing knowledge concerning the Jurassic of the entire world has just been completed.

As a result many geologists will be saved thousands of hours of labor in reading, digesting and interpreting the geological literature on the Jurassic, or in finding references to that literature. Removing such a time-consuming burden should greatly encourage research. The synthesis, however, is much more than a compendium, as the author discusses in considerable detail the characteristics of the marine faunal realms, climate, paleogeography, igneous activity and major earth-movements during Jurassic time. His deductions in regard to these subjects depend primarily on world wide faunal correlations which are based mainly on ammonites. As the deductions are valid only if the correlations are sound, great emphasis is placed on the principles of correlation and on their accuracy. The discussions on these subjects make interesting reading to all students of earth history and will be found very useful by college teachers.

The first chapter in the book is a discussion of classification and correlation, including definitions of such units as formations, zones, stages, and subsystems. The author includes the Callovian stage in the Middle Jurassic, instead of at the base of the Upper Jurassic, in order to conform with the arrangements originally proposed by von Buch and to produce a better balance of the subsystems. This arrangement is quite satisfactory in the reviewer's opinion, particularly because the Bathonian appears to be of much shorter duration than the adjoining stages. Concerning the use of stages, Arkell points out that most of the Jurassic stages based on sequences in northwest Europe can be recognized throughout the world. Above the middle Kimmeridgian, however, correlation of northwest Europe with other parts of the world is difficult, owing to sharp faunal differentiation. Consequently for the highest Jurassic above the middle Kimmeridgian, the term Volgian stage is used in Russia and the Arctic region and the term Tithonian stage is used throughout all other parts of the world excluding northwest Europe.

Most of the book, from pages 17 to 592, is a detailed discussion of the Jurassic stratigraphic paleontology of the world. This part is so arranged on a geographic basis that it is possible to find information on a particular stage in a particular country in a few seconds. The geologist who knows little about fossils will find for any area considerable stratigraphic data and many references to geologic publications. The author deliberately places emphasis on northwest Europe because it is the type area for most of the stages and furnishes the foundation for most of the correlations. He also deliberately abbreviates the discussion on North America because for that area an extensive literature in the English language is readily available. This is a wise procedure because any discussion that might be added in a few extra pages would soon be outdated by the numerous papers on the Jurassic of North America that are now being published, such as the U. S. Geological Surveys' Paleotectonic Map Folio of the Jurassic system.

The short discussions concerning North America are nevertheless useful and interesting. One of the most pertinent conclusions (p. 536) is that the *Cranocephalites* beds in the Cook Inlet area of Alaska are of Callovian instead of Bathonian age because they contain the ammonite *Reineckeia*, based on identifications of the reviewer. Likewise, approximately equivalent beds in Alberta, Canada, contain such Callovian ammonites as *Eurycephalites* and *Cadoceras* (p. 541), based on identifications by H. Frebold. Arkell emphasizes that L. F. Spath placed the arctic genus *Arctocephalites* and its subgenus *Cranocephalites* in the Bathonian mainly by deciding to reclassify the *Macrocephalites macrocephalus* zone as Bathonian (p. 392, 506) instead of basal Callo-

vian. Support for the Callovian age of the *Cranocephalites* beds in Alaska has been obtained recently by other discoveries of *Reineckeia* and of one specimen of *Hecticoceras*.

All these statements concerning the Callovian age of the *Arctocephalites* and *Cranocephalites* beds must be confirmed by adequate publications before their validity can be fully accepted. Assuming that they are true, however, a particular problem is posed by the fact that in the western interior of the United States many of the common pelecypod species range from beds of middle Bajocian age into beds of early Callovian age. Such an extended range for pelecypod species would not be in itself surprising if there were continuous sedimentation somewhere in the western interior during the Bathonian. If the Bathonian sea had retreated completely to the Arctic Ocean, it seems probable that most of the pelecypod species would have perished before the Callovian. The fact that they did not indicates that beds of Bathonian age do exist in the western interior of North America and that Frebold (Geol. Soc. Amer., Bull., v. 64, p. 1237, 1953) correctly identified the presence of beds of Bathonian age in the middle Fernie formation in Alberta. Relegating the beds containing *Cranocephalites* and *Arctocephalites* to the Callovian and searching for other beds of Bathonian age will doubtless require some reorientation in thinking by geologists concerned with Jurassic stratigraphy.

The final chapters of the book discuss many fascinating subjects such as evidence against continental drift during Jurassic time, for a land mass across the Indian Ocean from Madagascar to peninsular India, against the universality of ammonite faunas, ammonite migrations during the Late Jurassic, world wide regressions of seas and isolation of the Arctic Ocean during the Bathonian, and general correspondence of unconformities at many places in the world. The last part of the book contains a bibliography of more than 2800 references arranged geographically to conform with the treatment in the text. The plates are excellent. Thirty of them show Jurassic outcrops and sixteen illustrate some of the most useful Jurassic ammonites.

The reviewer feels that publication of the *Jurassic Geology of the World* marks a major breakthrough in the slow advancement in knowledge of stratigraphic paleontology and of its applications. Just consider what rapid progress could be made if similar syntheses were available for all the geologic systems!

RALPH W. IMLAY
U. S. Geological Survey
Washington 25, D.C.

PALÄONTOLOGIE UND PHYLOGENIE DER NIEDEREN TETRAPODEN, by Friedrich R. Freiherr von Huene. Jena, Gustav Fischer, 1956, p. xii,716, 690 Text-fig., 88DM.

A leading European student of fossil vertebrates has set down his concept of the phylogeny and classification of the amphibians and reptiles in a comprehensive volume which mentions nearly every extinct genus and illustrates most that are well known or critical. The book is particularly noteworthy for the attempt to present a classification which logically reproduces the phylogenetic implications of the embryological and morphological researches of Gadow, Holmgren, Jarvik, Säve-Söderbergh, Watson, and others. Any reader who is unfamiliar with this field should be warned that other phylogenetic interpretations are not only possible but also are more generally accepted today. It is unfortunate that limited space prevented discussion of alternative schemes. Nonetheless many of the departures from currently standard arrangement are significant advances, and the entire system deserves close comparison with those of Romer (Vertebrate Paleontology, Univ. Chicago Press, 1945) or Piveteau (Traité de Paléontologie, Tome V, Paris, 1955).

Von Huene's attempt at expressing phylogeny in classification is highly commendable. He has skillfully avoided the danger of undue multiplication of supra-ordinal groups. With a few notable exceptions the content of major tetrapod branches is much the same as in other modern classifications. For this reason his use of such terms as Urodelidia for Lepospondyli, Reptiliomorpha for Anapsida plus Anthracosauria, Sauromorpha for Diapsida, or Ponderopoda for Ceratopsia, seems an unnecessary modi-

fication of established nomenclature. Any phylogenetic classification is beset by two other difficulties: Proper allocation of transitional or stem groups and correct assignment of imperfectly known and aberrant forms, particularly if these are close to the separation of major stems. Ultimately "horizontal" categories must be used to provide a reasonable classification for such organisms.

Assignment of *Prolacerta* to the Squamata and *Bolosaurus* to pre-Eosuchian Sauromorpha are bold advances in phylogenetic classification. Polyphyletic origins of major groups are objectionable to biologists who consider it improbable that the similar fundamental plans of organization would have arisen more than once. Von Huene has abolished the long recognized class Amphibia for this reason, dividing its members among the Urodelidia and the Batrachomorpha and early Reptiliomorpha of the Eutetropoda. His revised nomenclature is thus consistent with the proposed phylogeny. However, the diphyletic origin of tetropods is far from firmly established, perhaps owing to the paucity of early Carboniferous fossils. Regardless of the antiquity of separation of ancestors of frogs and salamanders, similarities in the life history and anatomy of these most primitive living tetropods form a strong argument for their retention in a single class Amphibia.

On the other hand Von Huene has resorted to "horizontal" classification by placing the Order Captorhinidia in his branch Reptiliomorpha (because of their retention of cotylosaurian vertebrae) rather than in the Theromorpha. This makes the former branch essentially equivalent to the Anaspida rather than a strictly phyletic unit. Likewise inclusion of aistopods and the primitive microsaur family Adelogyrinidae in the Suborder Nectridia makes that group essentially equivalent to all Paleozoic lepospondyls except the lysorophids and microsaurs, an arrangement which conceals rather than emphasizes rather divergent phyletic lines.

Although the arrangement of Permian reptiles represents the phylogenetic positions well, the classification adopted suffers from difficulty in defining major groups. For example, the close unity of pelycosaurs and therapsids,—generally emphasized by placing them in a subclass Synapsida, is lost although the relationship is recognized. A relatively large number of orders of the Thermomorpha are recognized with insufficient higher groups to bring out their interrelationships. The aquatic sauropterygians and placodonts, whose relationship to other synapsids is not adequately demonstrated, deserve some type of separate grouping. If the Sauromorpha are derived from the Diadectomorphia, as Watson believes and von Huene, sometimes at least, implies the arrangement of Orders would be more logical if that branch followed the Testudinata and preceded the Captorhinidia and Thermorpha.

The picture of the origin and relationships of the diapsids ("Sauromorpha") is confused by the statement that Eosuchia were derived from the Diadectomorpha (p. 429) and from "higher Captorhinidia in part with clear diadectomorph inheritance" (p. 691), and by the double root of the Sauromorph branch of the phylogenetic diagram on p. 689. The uncertainty is understandable, for present knowledge of diapsid origins is meager.

Many years ago von Huene suggested that icthyosaurs were descendants of embolomerous labyrinthodonts. On the basis of the recently discovered *Tupilakosaurus* from the early Triassic of Greenland, which has a labyrinthodont skull accompanied by ichthyosaur-like vertebrae, von Huene has now removed the ichthyosaurs from the reptiles and united them with the majority of labyrinthodont amphibians in the branch Batrachomorpha. Unfortunately the specimen is not in articulation and the embolomerous reconstruction of the vertebral column from isolated centra and arches which closely resemble those of stereospondylous labyrinthodonts cannot be accepted without reservation. To derive the typically reptilian vertebrae of ichthyosaurs from those of advanced labyrinthodonts is a difficult morphological transformation. Until the homology of the superficially similar, short, checker-shaped centra of ichthyosaurs to the half-centra of embolomeres can be demonstrated beyond doubt, placing ichthyosaurs in the Batrachomorpha will

appear an exception to the use of vertebral structure as a fundamental basis for classification, which von Huene emphasizes.

Within some orders of mammal-like reptiles, particularly the Dicynodontia, von Huene has achieved a notable synthesis of the widely scattered and unrelated descriptions and has presented the essential features of these groups better than any previous account. Evolutionary trends within the order are summarized in a separate chapter and comparative table.

In summary, von Huene has added several blocks to the phylogenetic edifice, but the present state of knowledge has limited his efforts and may have caused him to misplace others in the course of his building.

The book is printed in large type. Illustrations are numerous but variable in quality, some are clear but others are sketchy and some have been so greatly reduced that thinness of line makes them difficult to study. Many lack adequate indications of size. A surprisingly large number of typographical errors suggest hasty proofreading but do not diminish the usefulness of the volume. It should find a prominent place on the desk of every student of Paleoherpetology.

JOSEPH T. GREGORY
Peabody Museum
Yale University,
New Haven

EINFÜRUNG IN DIE MIKROPALÄONTOLOGIE, by Horst Werner Matthes. S. Hirzel Verlag Leipzig, D.D.R. (Eastern Germany), 348 p., 1050 fig., 53 charts, 1956. *33*DM.

This book is an introduction to micropaleontology in a broad sense. Some emphasis is placed on groups of microfossils which have little practical use.

The groups are arranged arbitrarily in the following order: foraminifers (100 p., utilizing figures chiefly from Cushman); ostracodes (39 p.); radiolarians (7 p., including reproduction of 3 Clarke & Campbell plates); sponges (5 p.); echinoderms (4½ p., holothurians surprisingly are mentioned in only 10 lines and a few figures); conodonts (19 p., chiefly a translation of Fay's key to the genera and reproduction of his figures); scolecodonts (2 p.); otoliths (5½ p., terms like "sagitta" are used but not explained); calpionellids (2½ p., the part on Tintinnina in the *Treatise on Invertebrate Paleontology*, 1954, is not utilized); hystrichosphaeriids (4 p.); chitinozoans, *Nannoconus*, *Oligostegina*, bryozoans, anthozoans, and conularias (together 6½ p.); diatoms (3½ p.); charophytes (which in contrast to the expressed opinion are widely distributed in Paleozoic marine beds, 4 p.); other algae (5½ p.); silicoflagellates, ebriids, dinoflagellates, coccoliths and discoasterids (together 15 p.); spores and pollen (only 10 p.); and bacteria (1 p.).

The stratigraphic portion (48 p.) consists largely of examples and many charts, adapted for the most part from recent European literature. Much of this information will be of use to the practical paleontologist.

Remarks on history, facies, taxonomy, nomenclature, etc., are given under the heading General Micropaleontology (10 p.). The brief part on techniques (10 p.) lacks description of some important standard methods.

Each chapter includes numerous but poorly selected references; due to the lack of annotations they will, in many cases, be of little guidance for the beginning student. An extensive index (33 p.) concludes the work. The paper, the binding, and the format of the book are quite satisfactory; and the illustrations are well done.

KLAUS J. MÜLLER
State University of Iowa
Iowa City

A *Thunnus* FROM THE EOCENE DEPOSITS OF THE CAUCASUS, by P. G. Danil'chenko. *Translated* from Akademiia Nauk S.S.S.R., Doklady, t. 77, no. 5, p. 881–883, 1951.

Until recent times only one species of fossil fish was known with authenticity from the marine deposits of the Eocene age in the Caucasus, *Lyrolepis caucasicus*. The description was published by G. D. Romanovski about 45 years ago. In the middle and upper strata of these deposits, fossil remains of another species of bony fish are encountered frequently; it was apparently widespread in the Eocene Tethys.

Some of the skeletons and impressions of this fish are in the collections of the Paleon-

tological Institute of the Academy of Science of the U.S.S.R. There are some also among the exhibits of the Abkhazian Regional Museum (of the city of Sukhumi). Among the latter there is one large specimen very well preserved. A comparative study of these skeleton materials revealed that they belong to a new fossil species of tuna. The following is a short description of this species.

Thunnus abchazicus Danil'chenko, n. sp.

Vert. 40–41 (18+22–23), I D XI–XII, II D I+12–13+8, A II+11–12+7, P 33–36, V I+5.

A fish of large dimensions (in the adult), with the length of the body reaching 150 cm. from the tip of the snout to the end of the spinal column. The greatest height of the body composes 31–33 per cent of the length of the body; the length of the head about 28–30 per cent of its size. The mouth is large, the upper jaw ending opposite the middle of the orbit of the eye. The lower jaw projects somewhat in front. The teeth in both jaws are small and conical.

The vertebrae are massive and weakly elongated, almost square in projection but noticeably shortened in the rear part of the caudal section, near the base of the caudal fin. The trunk vertebrae are provided with narrow, but firm, parapophyses to which are attached 14–15 pairs of long, strongly deflected backward ribs. The length of the trunk part of the vertebral column represents about 42–44 per cent of the length of the entire vertebral column.

There are two dorsal fins. First dorsal fin is long, beginning opposite the 6th and ending at a vertical of the 17th vertebra. Anterior part of the fin is high, the length of the anterior rays (second–third) equals the length of seven trunk vertebrae. The interapophyses of the fin are long, clearly widened in their upper part, touching the distal ends of the neurapophysis. The second dorsal fin is separated from the first only by a small space, beginning opposite the 18th vertebra (of the last vertebra of the trunk section of the vertebral column). The base of this fin is almost twice as small as the base of the first dorsal fin.

Behind the fins are situated eight additional finlets composed of narrow bundles of strongly branched rays which are completely separated.

The anal fin begins opposite the 25th vertebra; clearly behind the vertical extension of the rear end of the second dorsal fin. The length of the base of this fin is somewhat longer than that of the second dorsal fin, and equals the length of the seven vertebrae lying opposite it. The length of the longest rays of the fin (fourth–fifth) equals the length of its base. The seven complementary finlets situated behind this fin are similar to those on the dorsal surface of the body.

The pectoral fins are affixed high on the sides of the body approximately at the middle of the distance between the line of the vertebral column and the abdominal profile of the body. They are composed of long slender rays strongly branched at their ends. The longest reach the vertical extension of the 16th vertebra. The width of the fin at its base equals one fifth of the greatest height of the body.

The ventral fins are noticeably shorter than the pectorals. They are situated somewhat in front of the latter.

The caudal fin is large; its upper and lower lobes are separated from one another by an angle of more than 90°. The distal ends of these lobes are somewhat curved backwards, and because of this the fin acquires a sort of semilunar form. The length of the longest rays of the fin equals 70–75 per cent of the greatest height of the body.

The caudal peduncle is slender and provided with short and weakly developed lateral keels which are situated opposite the three–four last caudal vertebrae. The hypural plate is small and embraced by the extreme rays of the fin.

For the holotype of this species I take the specimen deposited in the Abkhazian Regional Museum as No. 167–168. This specimen was found in the upper Eocene deposits along the middle current of the Gumist River, near the city of Sukhumi, and represents a double impression which is very well preserved but without the fore part of the head. The length of the impression is 110 cm.

Eight fossil species of the genus *Thunnus* are known from the Tertiary of Europe and America through the Recent, however all

of them differ noticeably from the above described *Thunnus abchazicus*.

Most similar to this species is the lower Eocene *Thunnus latior*, described by Agassiz from the fish cemetery Monte Bolca (Italy). It also differs from our Caucasian species by a series of essential features, such as: a lower body, a greater number of supplementary finlets, a more forward position of the second dorsal and especially anal fins, and also a somewhat different number of vertebrae and rays in the fins.

As was noted, *Thunnus abchazicus* is present in the Caucasus predominantly in the middle and upper Eocene, but is rarely present in the lower Oligocene (lower Khadum). The same is true for another Eocene fish—*Lyrolepis caucasicus* Romanovski, the scales of which are rarely found in the lower strata of the Khadum.

The presence of the Eocene species in the deposits of Khadum age points to a certain succession between the Eocene and Oligocene fauna, even though on the whole these faunas differ essentially among themselves.

DONALD P. DE SYLVA
University of Miami
Marine Laboratory,
Coral Gables

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1382, NOVEMBER, 1956

NOTICE

V INTERNATIONAL CONGRESS, INQUA

The Fifth Congress of the International Association on Quaternary Research is tentatively scheduled to be held in Madrid and Barcelona, September 20 to October 3, 1957. A request has been made from North America to have the meetings earlier to allow attendance before the start of the academic year.

The following sections will be represented at the Congress: Astronomy, Physics of the Earth, Climatic Pedology and Petrography of the Sediments, Morphology, Glacialogy, Hydrology and Limnology, Paleontology, Paleoanthropology, Palethnology, Geochronology, Paleoclimatology, Regional Quaternary.

The program will include communications on several specific subjects:

a) Study of shore lines—Director: C. A. Blank, Rome.
b) Glossary of the Quaternary—Director: E. Wegmann, Neuchâtel.
c) Correlation of the Pleistocene—Director: I. M. van der Vlerk, Leiden.
d) Recent tectonics—Director: J. Bourcart, Paris.
e) Pleistocene geologic map of western Europe—Director: P. Woldstedt, Hannover.

Matters related to this program should be addressed to the respective directors. General inquiries are to be sent to: M. L. Solé Sabarís, Instituto Geológico, Universidad, Barcelona, Spain.

A series of excursions will be conducted before, during, and after the Congress.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 6, P. 1383–1385, NOVEMBER 1956

SOCIETY RECORDS AND ACTIVITIES

The Gulf Coast Section of S.E.P.M. recently elected officers for 1957. The new officers, who assumed their duties on November 2, 1956, are listed below:

President: Lloyd M. Pyeatt, Sohio Petroleum Company, Houston, Texas.
Vice-President: J. O. Colle, 911 San Jacinto Building, Houston, Texas.
Secretary: Hervie Dillingham, Jr., Atlantic Refining Co., Houston, Texas.
Treasurer: Eleanor Caldwell, Humble Oil and Refining Co., Tallahassee, Florida.

PACIFIC SECTION
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

November 8, 1956, Ambassador Hotel, Los Angeles, California

Thursday Afternoon

Presiding: W. H. EASTON, President, Pacific Section, S.E.P.M., University of Southern California, and R. L. PIERCE, Secretary-Treasurer, Pacific Section, S.E.P.M., Richfield Oil Corporation

1. PRESERVATION OF DERIVATIVES OF CHLOROPHYLL IN POTENTIAL SOURCE BEDS OF PETROLEUM

WILSON L. ORR, JOHN R. GRADY, AND K. O. EMERY

University of Southern California, Los Angeles

The composition of detrital organic matter (decomposition products of plankton) which is buried in marine sediments varies according to the sedimentary environment. Quantitative measurements of the green pigment content of basin sediments (calculated as pheophytin) range from 103 to 34 ppm. of dry sediment in the surface zones of sediments from three basins off southern California, and from 77 to 1 ppm. at depths of 100 to 200 cm. in the sediment. Variations within basins are explained by height of water column through which detritus settles, oxygen content of the water, and total sedimentation rate. Variations with depth in the sediment are explained by variations in rate of decomposition in sediments of different character, extent of decomposition before burial, and variations in original organic content resulting from variable rates of deposition of clastics. Data allowing these explanations are relationships between green pigment content, organic matter (%N & %C), grain size, moisture content, and sedimentation rates of the sediments, together with various oceanographic characteristics of the water and topography of the bottom. These data are of interest in relation to the origin of petroleum since the green pigments are the source material from which the major porphyrins in petroleum are believed to have originated.

2. THE DETERMINATION OF GEOLOGICAL AGES BY RADIOACTIVE METHODS

CLAIRE PATTERSON

California Institute of Technology, Pasadena, California

The best absolute geological ages may be accurate to about one part in fifty, but such accuracy is uncommon. Several conditions must be met to obtain an accurate radioactive age. We must use a suitable mineral which has existed unchanged since it was formed. We must make accurate physical and chemical measurements. We must know the radioactive decay constants with exactness. At the present time a geologist will rarely encounter a situation where all of the above qualifications are fulfilled despite the many radioactive age methods which are available. Under these circumstances it will be most helpful to discuss only two methods which may be used frequently by geologists in the near future.

The "potassium 40-argon 40" method may become very important to geologists, especially to sedimentologists and paleontologists. The mass 40 isotope of potassium decays by electron capture to the mass 40 isotope of argon, an inert gas. It has been discovered that some authigenic minerals occurring in sediments, such as glauconite, retain all or nearly all of the radiogenic argon 40 which is formed within them. It seems probable that K^{40}/A^{40} ages can be obtained from these materials which will be

accurate to at least one part in twenty or better. The equipment which is needed to establish the techniques for this method is complicated and expensive. When the method has been established, inexpensive rapid and routine analytical procedures may be used and the limiting factors may well be the time and cost of sample procurement.

The "Larson" method shows great promise and may become one of the most important tools of the geologist in dating igneous rocks. In this method the age of a few milligrams of the mineral, zircon, is obtained by measuring the minute amounts of uranium and thorium in the mineral and also the minute amount of lead formed by the radioactive decay of the uranium and thorium. These measurements involve standard, routine, and rapid techniques and the limiting factor is usually the time and cost of obtaining the sample. Although the method is being used on an expanding scale, its validity has not yet been thoroughly established. The equipment for such studies is complicated and expensive. The claimed accuracy of the method is one part in five. In those cases where the method has been investigated by expensive and complicated procedures the accuracy has been shown to vary between one part in fifty to one part in two.

3. GENERAL RELATIONSHIPS BETWEEN FORAMINIFERA AND BATHYMETRY

ORVILLE L. BANDY

University of Southern California, Los Angeles, California

Investigations show striking general relationships between Foraminifera and bathymetry in modern seas. Offshore trends include a definite increase in species and foraminiferal number away from shore. Planktonic species may attain maximum percentages in the outer shelf, upper bathyal, and in deeper zones.

Among porcelaneous genera, quinqueloculine and triloculine genera are abundant in shoal marine waters whereas biloculine forms display a wide latitude of environmental preferences, from shoal to abyssal waters. Types inhabiting the continental shelves tend to have smooth edges, broad apertures, and short necks whereas those in deeper waters tend to have cylindrical necks, simple teeth, and serrate edges.

Hyaline genera display a diversity of trends. Species of *Uvigerina* are known to vary from mostly striate, to costate, to spinose and papillate species, with increasing depth of water. Species of *Bulimina* are smaller and less ornate in shoal waters, becoming larger and spinose in bathyal waters, and smaller and costate in abyssal waters. Species of *Bolivina* are small, thin-walled, variable, and striate in shoal marine waters, they tend to become larger, with heavier tests, sinuate sutures, and more pronounced ornamentation in the bathyal zone.

Arenaceous species reveal many singular bathymetric trends also. For example, species of *Textularia* with flaring chambers are common in shoal inshore waters of many regions. Elongate species, round or elliptical in cross section, are more generally distributed both in shallow and in deeper waters. Slender species with siphonate peripheries occur in the upper bathyal zone and in deeper waters.

Thursday Evening

S.E.P.M. Annual Dinner and Evening Sessions

Presiding: W. H. EASTON, President

CHANGING RULERS OF THE EARTH

J. J. GALLOWAY

Indiana University, Bloomington, Indiana

A ruler is a race which can live in any part of the earth it wants to in spite of other races which contest its right to live there. The requirements for dominance over other organisms are large size, strength, speed, alertness, cunning, fierceness, the urge to overcome other races, persistence, the ability to endure the climate, and necessary food. In later human history some of the rulers have been the Macedonians under Alexander, the Romans under Caesar, the Barbarians, the Mongolians under Genghis Khan, the Spaniards after the discovery of America, followed by the English. More recently the Germans and Japanese have tried to be conquerors and now the Russians have the urge.

During geologic time many different races of organisms have been dominant, first in the sea and since the Pennsylvanian the

rulers have lived on the land. The trilobites ruled in the Cambrian, the cephalopods in the Ordovician, the eurypterids in the Silurian and the fishes in the Devonian. The lizards were more powerful in the Permian, when they introduced the art of bluffing, trying to seem larger and more powerful than they really were.

During the Mesozoic era the seas, the land, and the air were dominated by the reptiles and the rulers of the land were first one race of dinosaurs after another, but each race became extinct immediately following its greatest success.

The Cenozoic era has been dominated by the mammals. The *Uintatherium*, the *Brontotherium*, the giant pigs, giant cats and finally the mammoths, which became extinct about five thousand years ago. Man, with his cunning, adaptability and particularly his weapons, rose to dominance about the time the power of the larger mammals declined. Powerful species seem to last about five million years before succumbing to over-specialization and racial senescence. Man is destined to last a few million years, to decline in numbers and power and to become extinct. Man is not likely to kill himself off, but will die a natural death, the same as does an individual. After man is gone there will be hosts of other creatures living, and the struggle for dominance is likely to be between the carnivores and the insects, or perhaps some new race of creatures will arise and claim to be the Rulers of the Earth.

S.E.P.M. ELECTS NEW OFFICERS
April, 1957–March, 1958

President: RICHARD V. HOLLINGSWORTH, Paleontological Laboratory, Midland, Texas

Past-President: ROBERT R. SHROCK, Massachusetts Institute of Technology, Cambridge, Massachusetts

Vice-President: STUART A. LEVINSON, Humble Oil and Refining Company, Houston, Texas

Secretary-Treasurer: SAMUEL P. ELLISON, JR., University of Texas, Austin, Texas

Editor, Journal of Paleontology: M. L. THOMPSON, University of Kansas, Lawrence, Kansas

Editor, Journal of Sedimentary Petrology: JACK L. HOUGH, University of Illinois, Urbana, Illinois

PRICE LIST

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

P.O. Box 979, Tulsa 1, Oklahoma

		Non-Members Per Vol.	Members Per Vol.
JOURNAL OF PALEONTOLOGY			
Vol. 1 (1927)	Complete in 4 Nos., Reprinted 1948		
	Paper-bound copies	$ 6.00	$ 6.00
	Cloth-bound copies	6.50	6.50
Vol. 2 (1928)	Complete in 4 Nos.	12.00	7.00
Vol. 4 (1930)	Only Supplement 1 Available	3.00	1.75
Vols. 5 to 8 (1931-34)	Each Complete in 4 Nos.	12.00	7.00
Vols. 9 to 11 (1935-37)	Each Complete in 8 Nos.	24.00	14.00
Vols. 12 to 19 (1938-45)	Each Complete in 6 Nos.	18.00	10.50
Vols. 21 and 22 (1947-48)	Each Complete in 6 Nos.	18.00	10.50
Vol. 24 (1950)	Only Nos. 2 to 6 Available	15.00	8.75
Vol. 25 (1951)	Only Nos. 3 to 6 Available	12.00	7.00
Vols. 26-30 (1952-56)	Each Complete in 6 Nos.	18.00	10.50
SINGLE ISSUES	Non-Members, $3.00; Members, $1.75		
JOURNAL OF SEDIMENTARY PETROLOGY			
Vol. 1 (1931)	Only No. 2 Available	2.00	1.50
Vols. 2 and 3 (1932-33)	Each Complete in 3 Nos.	6.00	4.50
Vol. 4 (1934)	Only Nos. 2 and 3 Available	4.00	3.00
Vol. 5 (1935)	Only Nos. 1 and 2 Available	4.00	3.00
Vol. 6 (1936)	Only No. 3 Available	2.00	1.50
Vol. 7 (1937)	Only No. 2 Available	2.00	1.50
Vol. 18 (1948)	Only No. 3 Available	2.00	1.50
Vol. 20 (1950)	Complete in 4 Nos.	8.00	6.00
Vol. 21 (1951)	Only Nos. 1, 3, and 4 Available	6.00	4.50
Vols. 22 and 23 (1952-53)	Each Complete in 4 Nos.	8.00	6.00
Vol. 24 (1954)	Only No. 4 Available	2.00	1.50
Vols. 25 and 26 (1955-56)	Each Complete in 4 Nos.	8.00	6.00
SINGLE ISSUES	Non-Members, $2.00; Members, $1.50		

SPECIAL PUBLICATIONS

Turbidity Currents and the Transportation of Coarse Sediments to Deep Water, A Symposium (1951) ..... Non-Members, $2.75; Members, $2.25 per copy

*Recent Marine Sediments, Reprinted with Additions (1955) ..... Non-Members, $5.00; Members, $4.00 per copy

*Finding Ancient Shorelines, A Symposium (1956) .. Non-Members, $3.00; Members, $2.50 per copy

*Regional Aspects of Carbonate Deposition, A Symposium (1957) ..... Non-Members, $4.50; Members, $3.50 per copy

*Members of AAPG may purchase at member price.

Annual Membership Dues, including the Journal of Paleontology ..... $ 8.00

Annual Membership Dues, including the Journal of Sedimentary Petrology ..... $ 5.00

Annual Membership Dues, including Both Journals $13.00

Non-Member Subscriptions to Journal of Paleontology ..... $15.00; Foreign, $15.40

Non-Member Subscriptions to Journal of Sedimentary Petrology ..... $ 6.00; Foreign, $ 6.40

Agents are allowed a 10% discount on back numbers and subscriptions.

JOURNAL OF PALEONTOLOGY

INDEX TO VOLUME 30

AUTHOR INDEX

		No.	Page
1.	ACCORDI, BRUNO, A new genus of Lower Triassic holostean fish from the Dolomite Alps	2	345
	ALF, RAYMOND, see HOUGH, JEAN (48)		
2.	ANDREWS, HENRY N., JR., Pars 28–29, Fossilium Catalogus II. by W. Jongmans & F. M. Wonnacott (Review of)	2	406
	ARTUSY, J. C., see ARTUSY, R. L. (3)		
3.	ARTUSY, R. L., and ARTUSY, J. C., The use of food coloring as a new technique for staining microfossils	4	969
4.	BARNARD, TOM, An unusual wormtube from the lower Lias	5	1273
5.	BAYER, FREDERICK M., The Trachypsammiacea, Permian Octocorallia	6	1375
6.	BLACK, CRAIG C., and WOOD, ALBERT E., Variation and Tooth-replacement in a Miocene mylagaulid rodent	3	672
	BLACKMON, PAUL, see TODD, RUTH (119)		
7.	BOLIN, EDWARD J., Upper Cretaceous Foraminifera, Ostracoda, and Radiolaria from Minnesota	2	278
	BOLTON, THOMAS E., see SINCLAIR, G. WINSTON (94)		
8.	BOUCOT, A. J., and GILL, EDMUND D., *Australocoelia*, a new Lower Devonian brachiopod from South Africa, South America, and Australia	5	1173
9.	BRADLEY, JOHN S., A teratoid *Parafusulina*	2	303
	BROOKLEY, ARTHUR C., JR., see SWEET, WALTER C. (108)		
10.	BROOKS, H. K., and CASTER, KENNETH E., *Pseudoarctolepis sharpi*, n. gen., n. sp. (Phyllocaridia), from the Wheeler shale (Middle Cambrian) of Utah	1	9
11.	CAMPBELL, K. S. W., Some Carboniferous productid brachiopods; New South Wales	3	463
12.	CASTER, KENNETH E., and KJELLESVIC-WAERING, ERIK N., Some notes on the genus *Dolichopterus* Hall	1	19
13.	CASTER, KENNETH E., and EATON, THEODORE H., JR., Microstructure of the plates in the carpoid echinoderm *Paranacystis*	3	611
	CASTER, KENNETH E., see BROOKS, H. K. (10)		
14.	CHILINGAR, GEORGE V., About dynamics of septal development in tetracorals during ontogeny, by K. G. Voynovskiy-Kriger (Review of)	2	406
15.	CHOQUETTE, GEORGE B., A new Devonian Charophyte	6	1371
16.	COBBAN, W. A., ROHRER, W. L., and ERDMANN, C. E., Discovery of the Carlile (Turonian) ammonite *Collignoniceras woollgari* in northwestern Montana	5	1269
17.	COLLINSON, CHARLES W., The Mississippian nautiloid genus *Tylodiscoceras* in Kentucky and Tennessee	6	1367
18.	COOPER, G. ARTHUR, A new upper Canadian fauna from a deep well in Tennessee	1	29
19.	COOPER, G. ARTHUR, New Pennsylvanian brachiopods	3	521
20.	COOPER, G. ARTHUR, *Pustulata*, new name for the Devonian brachiopod *Pustulina*, preoccupied	3	769
21.	CORNWALL, IRA E., Identifying fossil and Recent barnacles by the figures in the shell	3	646
22.	COX, L. R., Jurassic Mollusca from Peru	5	1179
23.	CRANE, MARILYN JOYCE, and KELLY, WILLIAM A., A new occurrence of Mississippian Ostracoda in Michigan	4	869
24.	DAVID, LORE ROSE, Tertiary anacanthin fishes from California and the Pacific Northwest; their paleoecological significance	3	568
25.	DELAND, CHARLES R., and SHAW, ALAN B., Upper Cambrian trilobites; western Wyoming	3	542
26.	DE LAUBENFELS, M. W., Dinosaur extinction: one more hypothesis	1	207
27.	DE SYLVA, DONALD P., A *Thunnus* from the Eocene deposits of the Caucasus, by P. G. Danil'-chenko (Review of)	6	1379
28.	DORR, JOHN A., JR., Anceney local mammal fauna, latest Miocene, Madison Valley formation, Montana	1	62
29.	DOWNS, THEODORE, A new pinniped from the Miocene of southern California: with remarks on the Otariidae	1	115
	EATON, THEODORE H. JR., see CASTER, KENNETH E. (13)		
30.	ECHOLS, DOROTHY JUNG, and GOUTY, JOHN J., Fern Glen (Mississippian) Ostracoda	6	1315
31.	ELIAS, MAXIM K., A revision of *Fenestella subantiqua* and related Silurian fenestellids	2	314

		No.	Page
32.	EMERSON, WILLIAM K., Upwelling and associated marine life along Pacific Baja California, Mexico	2	393
	ERDMANN, C. E., see COBBAN, W. A. (16)		
33.	FLOWER, ROUSSEAU H., Cephalopods from the Canadian of Maryland	1	75
34.	FLOWER, ROUSSEAU H., Some endoceroids from the El Paso limestone	1	97
35.	FLOWER, ROUSSEAU H., Some paradoxes in taxonomy with reference to the Protista	3	700
36.	FRANKEL, LARRY, Value of mollusks in the zonation of the "Peorian" loess of Nebraska	5	1158
37.	FRY, WAYNE L., New cordaitean cones from the Pennsylvanian of Iowa	1	35
	FURNISH, W. M., see GLENISTER, BRIAN F. (41)		
	FURNISH, W. M., see MILLER, A. K. (66)		
	FURNISH, W. M., see MILLER, A. K. (67)		
38.	GALLITELLI, EUGENIA MONTANARO, *Khmeria* and *Trachypsammia* from the Permian of Sosio, Sicily	4	876
39.	GALLOWAY, J. J., and ST. JEAN, J., JR., A bibliography of the order Stromatoporoidea	1	170
40.	GAZIN, C. LEWIS, The occurrence of Paleocene mammalian remains in the Fossil Basin of southwestern Wyoming	3	707
	GILL, EDMUND D., see BOUCOT, A. J. (8)		
41.	GLENISTER, BRIAN F., MILLER, A. K., and FURNISH, W. M., Upper Cretaceous and early tertiary nautiloids from Western Australia	3	492
	GOUTY, JOHN J., see ECHOLS, DOROTHY JUNG (30)		
42.	GREEN, MORTON, The lower Pliocene Ogallala—Wolf Creek vertebrate fauna, South Dakota	1	146
43.	GREGORY, JOSEPH T., Paläontologie und phylogenie der niederen tetrapoden, by Fredrich R. Freiherr von Huene (Review of)	6	1377
44.	HARRINGTON, HORACIO J., Olenellidae with advanced cephalic spines	1	56
45.	HARRIS, R. W., and MCNULTY, C. L., JR., Notes concerning a Senonian valvulinerian	4	865
46.	HIBBARD, CLAUDE W., *Microtus pennsylvanicus* (ORD) from the Hay Springs local fauna of Nebraska	5	1263
47.	HOFKER, J., Tertiary Foraminifera of coastal Ecuador: Part II, additional notes on the Eocene species	4	891
48.	HOUGH, JEAN, and ALF, RAYMOND, A Chadron mammalian fauna from Nebraska	1	132
49.	HOUGH, JEAN, A new insectivore from the Oligocene of the Wind River Basin, Wyoming, with notes on the taxonomy of the Oligocene Tenrecoidea	3	531
50.	HUDSON, R. G. S., Tethyan Jurassic hydroids of the family Milleporidiidae	3	714
51.	IMLAY, RALPH W., Stratigraphic and geographic range of the early Cretaceous ammonite *Homolsomites*	5	1143
52.	IMLAY, RALPH W., Jurassic geology of the world, by W. J. Arkell (Review of)	6	1376
53.	IRELAND, H. A., Upper Pennsylvanian arenaceous Foraminifera from Kansas	4	831
54.	JOHNSON, J. HARLAN, *Archaeolithophyllum*, a new genus of Paleozoic coralline algae	1	53
55.	JOHNSON, J. HARLAN, Ancestry of the coralline algae	3	563
56.	KARPECK, JOHN J., Devonian of the Russian Platform, collection of reports (Review of)	4	981
	KELLY, WILLIAM A., see CRANE, MARILYN JOYCE (23)		
57.	KIER, PORTER M., Separation of interambulacral columns from the apical system in the Echinoidea	4	971
58.	KING, PHILIP B., Atlas of paleogeographic maps of North America, by Charles Schuchert (Review of)	4	986
	KJELLESVIG-WAERING, ERIK N., see CASTER, KENNETH E. (12)		
59.	KNIGHT, RAYMOND L., Permian fusulines from Nevada	4	773
	KOENIG, JOHN W., see STRIMPLE, HARREL L. (106)		
	KOPF, RUDOLF W., see YOCHELSON, ELLIS L. (142)		
60.	LEHMANN, E. P., A technique of stereophotomicrography for illustrations in micropaleontology	3	757
	LEUTZE, WILLARD P., see SWEET, WALTER C. (110)		
61.	LOCHMAN, CHRISTINA, The evolution of some Upper Cambrian and Lower Ordovician trilobite families	3	445
	LOKKE, D. H., see THOMPSON, M. L. (117)		
	LOKKE, D. H., see VERVILLE, G. J. (124)		
62.	MAC DONALD, J. R., A new Clarendonian mammalian fauna from the Truckee formation of western Nevada	1	186
63.	MAC DONALD, J. R., A Blancan mammalian fauna from Wichman, Nevada	1	213
64.	MAC DONALD, J. R., The North American anthracotheres	3	615
	MC NULTY, C. L., JR., see HARRIS, R. W. (45)		
65.	MELVILLE, R. V., Classification of clypeasteroid echinoids, by J. Wyatt Durham (Review of)	4	983
66.	MILLER, A. K., and FURNISH, W. M., An *Aturia* from eastern Cuba	5	1154

		No.	Page
67.	MILLER, A. K., and FURNISH, W. M., An *Aturoidea* from Austria	5	1155
	MILLER, A. K., see GLENISTER, BRIAN F. (41)		
	MILLER, A. K., see SWEET, WALTER C. (109)		
68.	MILLER, HALSEY W., JR., The index value of Silurian Foraminifera and some new forms from wells in Kansas	6	1350
69.	MÜLLER, KLAUS J., Triassic conodonts from Nevada	4	818
70.	MÜLLER, KLAUS J., Taxonomy, nomenclature, orientation, and stratigraphic evaluation of conodonts	6	1324
71.	MÜLLER, KLAUS J., Einführung in die mikropaläontologie, by Horst Werner Matthes (Review of)	6	1379
	MÜLLER, KLAUS J., see RHODES, F. H. T. (85)		
72.	NEWELL, NORMAN D., Der grossablauf der stammesgeschichtlichen entwicklung, by Arno Hermann Müller (Review of)	5	1275
73.	NOREM, W. L., An improved method for separating fossil spores and pollen from siliceous rocks	5	1258
74.	OLIVER, WILLIAM A., *Tornoceras* from the Devonian Onondaga limestone of New York	2	402
75.	OMARA, S., New Foraminifera from the Cenomanian of Sinai, Egypt	4	883
76.	PACKARD, EARL L., An *Engonoceras* from central Oregon	2	398
77.	PALMER, ALLISON R., The type species of *Litocephalus* Resser, 1937, (Trilobita)	3	608
78.	PAMENTER, CHARLES B., *Imitoceras* from the Exshaw formation of Alberta	4	965
79.	PEABODY, F. E., Ichnites from the Triassic Moenkopi formation of Arizona and Utah	3	731
80.	PIERCE, RICHARD L., Upper Miocene Foraminifera and fish from the Los Angeles area, California	6	1288
81.	PURI, HARBANS S., Two new Tertiary ostracode genera from Florida	2	274
82.	RAINWATER, E. H., Geology of Jackson County, Florida, by Wayne E. Moore (Review of)	4	989
83.	RASETTI, FRANCO, Revision of the Trilobite genus *Marywillia* Walcott	5	1266
84.	RAUP, D. M., *Dendraster*: a problem in echinoid taxonomy	3	685
85.	RHODES, F. H. T., and MÜLLER, KLAUS J., Conodont genus *Prioniodus* and related forms	3	695
	ROHRER, W. L., see COBBAN, W. A. (16)		
86.	RUSSELL, LORIS S., Nonmarine Mollusca from the North Park formation of Saratoga Valley, Wyoming	5	1260
87.	SCHOEWE, WALTER H., Geographic locations and stratigraphic horizon of Pennsylvanian fossil footprints discovered in Osage County, Kansas by B. F. Mudge in 1873	2	389
88.	SCOTT, HAROLD W., *Swartzochilina*, new genus of isochilinid ostracode	6	1374
89.	SHAW, ALAN B., *Acrocephalites? glomeratus* Walcott, 1916	1	46
90.	SHAW, ALAN B., A Cambrian *Aphelaspis* fauna from Steele Butte, near Boulder, Wyoming	1	48
91.	SHAW, ALAN B., Notes on *Modocia* and Middle Cambrian trilobites from Wyoming	1	141
92.	SHAW, ALAN B., Quantitative trilobite studies I: the statistical description of trilobites	5	1209
	SHAW ALAN B., see DELAND, CHARLES R. (25)		
93.	SILBERLING, N. J., "*Trachyceras* zone" in the Upper Triassic of the western United States	5	1147
94.	SINCLAIR, G. WINSTON, and BOLTON, THOMAS E., Notes on halysitid corals	1	203
95.	SINCLAIR, G. WINSTON, Notes on some Ordovician sponges and their names	3	760
96.	SMITH, MARVIN L., Some ostracods from the Middle Devonian Ledyard and Wanakah members of the Ludlowville formation in western New York	1	1
97.	SOHN, I. G., The transformation of opaque calcium carbonate to translucent calcium fluoride in fossil Ostracoda	1	113
	ST. JEAN, J., JR., see GALLOWAY, J. J. (39)		
98.	STARRETT, ANDREW, Pleistocene mammals of the Berends fauna of Oklahoma	5	1187
99.	STEARN, COLIN W., A new echinoid from the Upper Devonian of Alberta	3	741
100.	STEHLI, FRANCIS G., *Dielasma* and its external homeomorph *Beecheria*	2	299
101.	STEHLI, FRANCIS G., Notes on oldhaminid brachiopods	2	305
102.	STEPHENSON, LLOYD WILLIAM, A new bivalve genus and species from the Ripley formation of Mississippi	3	752
103.	STEVENSON, ROBERT E., Observations on the morphology of *Astrodapsis*	2	338
104.	STEWART, GRACE ANNE, and SWEET, WALTER C., Conodonts from the Middle Devonian bone beds of central and west-central Ohio	2	261
105.	STOVER, LEWIS E., Ostracoda from the Windom shale (Hamilton) of western New York	5	1092
106.	STRIMPLE, HARREL L., and KOENIG, JOHN W., Mississippian microcrinoids from Oklahoma and New Mexico	5	1225

		No.	Page
107.	SWARTZ, FRANK M., and WHITMORE, FRANK C., JR., Ostracoda of the Silurian Decker and Manlius limestones in New Jersey and eastern New York	5	1029
108.	SWEET, WALTER C., and BROOKLEY, ARTHUR C., JR., An *Endolobus* from the Beaver Bend limestone (Chester) of Indiana	1	101
109.	SWEET, WALTER C., and MILLER, A. K., Goniatites from the Middle Devonian Columbus limestone of Ohio	4	811
110.	SWEET, WALTER C., and LEUTZE, WILLARD P., A restudy of the Silurian nautiloid genus *Pristeroceras* Ruedemann	5	1159
	SWEET, WALTER C., see STEWART, GRACE ANNE (104)		
111.	TASCH, PAUL, Three general principles for a system of classification of fossil conchostracans	5	1248
112.	TEICHERT, CURT, How many fossil species?	4	967
113.	TEICHERT, CURT, Stratigraphical paleontology, by E. Neaverson (Review of)	4	984
114.	TEMPLE, J. T., Phacopid ontogenies	5	1199
115.	THALMANN, HANS E., Bibliography and index to new genera, species, and varieties of Foraminifera for the year 1954	2	352
116.	THOMPSON, M. L., and ZELLER, DORIS NADINE, *Profusulinella* in western Utah	2	333
117.	THOMPSON, M. L., VERVILLE, G. J., and LOKKE, D. H., Fusulinids of the Desmoinesian-Missourian contact	4	793
	THOMPSON, M. L., see VERVILLE, G. J. (124)		
118.	TISCHLER, HERBERT, A new Mississippian tetracoral from Death Valley, California	1	110
119.	TODD, RUTH, and BLACKMON, PAUL, Calcite and aragonite in Foraminifera	1	217
120.	TOOMEY, DONALD F., Addendum to a bibliography of the family Fusulinidae	6	1360
121.	TSUDA, KARYU, Faunas and facies of some middle Miocene deposits in Japan	4	974
122.	TWINING, JOHN T., Occurrence of *Spinaptychus* in Texas	6	1370
123.	UNKLESBAY, A. G., and YOUNG, ROBERT S., Early Ordovician nautiloids from Virginia	3	481
124.	VERVILLE, G. J., THOMPSON, M. L., and LOKKE, D. H., Pennsylvanian fusulinids of eastern Nevada	6	1277
	VERVILLE, G. J., see THOMPSON, M. L. (117)		
125.	VOKES, H. E., Notes on the Nucinellidae (Pelecypoda) with description of a new species from the Eocene of Oregon	3	652
126.	VOKES, H. E., Notes on, and rectifications of, pelecypod nomenclature	3	762
127.	VOKES, H. E., Some pelecypod illustrations of the effect of the Copenhagen decision defining the limits of generic homonymy	3	765
128.	WAITE, R. H., Upper Silurian Brachiopoda from the Great Basin	1	15
129.	WEISS, MALCOLM P., Designation of type of *Plectorthis plicatella minnesotensis* Weiss, 1955	1	219
130.	WELLS, JOHN W., *Receptaculites* in the Upper Devonian of New York	3	747
131.	WELLS, JOHN W., The ammonoids *Koenenites* and *Beloceras* in the Upper Devonian of New York	3	749
132.	WHITE, WILLIAM R., Pliocene and Miocene Foraminifera from the Capistrano formation, Orange County, California	2	237
	WHITMORE, FRANK C., JR., see SWARTZ, FRANK M. (107)		
133.	WHITTINGTON, HARRY B., Beecher's supposed odontopleurid protaspis is a phacopid	1	104
134.	WHITTINGTON, HARRY B., Type and other species of Odontopleuridae (Trilobita)	3	504
135.	WHITTINGTON, HARRY B., Photographing small fossils	3	756
136.	WHITTINGTON, HARRY B., The trilobite family Isocolidae	5	1193
137.	WHITTINGTON, HARRY B., Beecher's lichid protaspis and *Acanthopyge consanguinea* (Trilobita)	5	1200
138.	WILIMOVSKY, NORMAN J., *Protoscaphirhynchus squamosus*, a new sturgeon from the Upper Cretaceous of Montana	5	1205
139.	WILSON, JAMES LEE, Stratigraphic position of the Upper Devonian branchiopod *Rhabdostichus* in the Williston Basin	4	959
140.	WILSON, JAMES LEE, Revisions in nomenclature and new species of Cambro-Ordovician trilobites from the Marathon Uplift, West Texas	6	1341
	WOOD, ALBERT E., see BLACK, CRAIG C. (6)		
141.	WOODRING, W. P., *Agasoma sinuatum* from the Miocene of Cuyama Valley, California	3	712
142.	YOCHELSON, ELLIS L., and KOPF, RUDOLF W., a new Devonian spinose platyceratid gastropod	5	1170
143.	YOUNG, ROBERT S., Lower Canadian brachiopods from Virginia	5	1165
	YOUNG, ROBERT S., see UNKLESBAY, A. G. (123)		

SUBJECT INDEX

Acanthopyge consanguinea: lichid protaspis (137).
Acrocephalites? glomeratus: Cambrian, Wyoming (89).
Agasoma sinuatum: Miocene, California (141).
Alberta: cephalopod, Devonian (78); new echinoid, Devonian (99).
algae: coralline ancestry (55); Paleozoic (54).
ammonoids: *Koenenites* and *Beloceras*, Devonian, New York (131); *Collignoniceras woollgari*, Cretaceous, Montana (16); *Homolsomites*, Cretaceous (51).
Anthracotheres: Miocene, Oligocene, North American (64).
Aphelaspis: Cambrian, Wyoming (90).
aragonite: Foraminifera (119).
Archaeolithophyllum: new algae, Paleozoic (54).
Arizona: Ichnites, Triassic (79).
Astrodapsis: morphology (103).
Aturia: Oligocene, Cuba (66).
Aturoidea: Eocene, Austria (67).
Australia: nautiloids, Cretaceous and Tertiary (41); new brachiopod, Devonian (8).
Australocoelia: Devonian, South Africa, South America, and Australia (8).
Austria: *Aturoidea*, Eocene (67).
Baja California: marine life (32).
barnacles: fossil and Recent (21).
Beecheria: homeomorph of *Dielasma* (100).
Beloceras: Devonian, New York (131).
bibliography: Foraminifera, 1954 (115); Fusulinidae, addendum (120); Stromatoporoidea (39).
Blancan: mammals, Nevada (63).
brachiopod: new Devonian, South Africa, South America, and Australia (8); new Pennsylvanian (19); oldhaminid (101); Ordovician, Tennessee (18); Ordovician, Virginia (143); Paleozoic (100); *Plectorthis plicatella minnesotensis*, type (129); productids, Carboniferous, New South Wales (11); *Pustulata*, new name, Devonian (20); Silurian, Great Basin (128).
branchiopod: *Rhabdostichus*, Devonian, Montana (139).
Brazil: echinoderm, Devonian (13).
bryazoans: Silurian (31).
calcite: Foraminifera (119).
calcium carbonate: transformation to calcium fluoride in Ostracoda (97).
calcium fluoride: from calcium carbonate in Ostracoda (97).
California: fish, Tertiary (24); Foraminifera and fish, Miocene (80); Foraminifera, Pliocene and Miocene (132); gastropod, Miocene (141); mammals, Miocene (29); tetracoral, Mississippian (118).
Cambrian: Phyllocaridia, Utha (10); trilobite evolution (61); trilobites, Wyoming (25, 89, 90, 91).
Cambro-Ordovician: trilobite revisions, Texas (140)
Canada: Alberta cephalopod, Devonian (78); new Charophyte, Devonian (15).
Carboniferous: productid brachiopods, New South Wales (11).
Causasus: fish, Eocene (27).
Cenomanian: Foraminifera, Egypt (75).
cephalic spines: Olenellids (44).
Cephalopods: *Aturia*, Cuba (66); *Aturoidea*, Eocene, Austria (67); endoceroids, Ordovician, Texas (34); *Endolobus*, Mississippian, Indiana (108); *Engonoceras*, Cretaceous, Oregon (76); goniatites, Devonian, Ohio (109); *Imitoceras*, Devonian, Alberta (78); *Koenenites* and *Beloceras*, Devonian, New York (131); nautiloids, Ordovician, Virginia (123); nautiloids, Cretaceous and Tertiary, Australia (41); Ordovician, Maryland (33); *Pristeroceras*, Silurian (110); *Spinaptychus*, Cretaceous, Texas (122); *Tornoceras*, Devonian, New York (74); Triassic, western United States (93).
Charophyte: Devonian, Canada (15).
Clarendonian: mammals, Nevada (62).
classification: conchostracans (111).
Collignoniceras woollgari: ammonite, Cretaceous, Montana (16).
conchostracans: classification (111).
conodonts: Devonian, Ohio (104); general discussion of (70); *Prioniodus* and related forms (85); Triassic, Nevada (69).
corals: halysitid (94); Mississippian, California (118); Permian, Sicily (38); septal development (14); Trachypsammiacea, Permian (5).
Cordaitean cones: Pennsylvanian, Iowa (37).
Cretaceous: ammonite (51); ammonite, Montana (16); cephalopod, Oregon (76); cephalopod, Texas (122); fish, Montana (138); Foraminifera, Egypt (75); Foraminifera, Ostracoda, and Radiolaria, Minnesota (7); nautiloids, Australia (41); new pelecypod, Mississippi (102); valvulinerian, Gulf Coast (45).
Cuba: *Aturia*, Oligocene (66).

Desmoinesian-Missourian contact: fusulinids (117).
Dendraster: echinoid Taxonomy (84).
Devonian: ammonoids, New York (131); branchiopod, Montana (139); cephalopod, Alberta (78); cephalopod, New York (74); cephalopods, Ohio (109); conodonts, Ohio (104); echinoderm, Brazil (13); gastropod, Ontario (142); new brachiopod name (20); new brachiopod, South Africa, South America, and Australia (8); new charophyte, Canada (15); new echinoid, Alberta (99); ostracodes, New York (96, 105); *Receptaculites*, New York (130); Russian Platform (56).
Dielasma: homeomorph *Beecheria* (100).
dinosaur: extinction (26).
Dolichopterus: Silurian, eurypterid (12).
echinoderm: *Paranacystis*, Devonian, Brazil (13).
echinoid: *Astrodapsis*, morphology (103); clypeasteroid, classification (65); *Dendraster*, taxonomy (84); Devonian, Alberta (99).
Echinoidea: interambulacrals and apical system (57).
Ecuador: Foraminifera, Tertiary (47).
Egypt: Foraminifera, Cretaceous (75).
Endolobus: Mississippian, Indiana (108).
England: worm tube, Lias (4).
Engonoceras: Cretaceous, Oregon (76).
Eocene: *Aturoidea*, Austria (67); fish, Caucasus (27); new Pelecypoda, Oregon (125).
eurypterid: *Dolichopterus*, Silurian (12).
evolution: phyletic (72); trilobites, Cambrian and Ordovician (61).
facies: Miocene, Japan (121).
faunas: Miocene, Japan (121).
Fenestella subantiqua: Silurian fenestellid (31).
Fish: anacanthin, Tertiary, California (24); holostean, Triassic, Italy (1); Miocene, California (80); sturgeon, Cretaceous, Montana (138); *Thunnus*, Eocene, Caucasus (27).
Florida: geology of Jackson County (82); new ostracodes, Tertiary (81).
footprints: Pennsylvanian, Kansas (87).
Foraminifera: 1954 bibliography (115); Cretaceous, Egypt (75); Cretaceous, Minnesota (7); mineralogy (119); Miocene, California (80); Pennsylvanian, Kansas (53); Pliocene and Miocene, California (132); Silurian, Kansas (68); Tertiary, Ecuador (47).
Fossilium catalogus: review of (2).
fusulines: Permian, Nevada (59).
Fusulinidae: bibliography addendum (120).
fusulinids: Desmoinesian-Missourian contact (117); Pennsylvanian, Nevada (124); *Profusulinella*, Pennsylvanian, Utah (116).
gastropod: *Agasoma sinuatum*, Miocene, California (141); platyceratid, Devonian, Ontario (142).
geology: Jackson County, Florida (82).
goniatites: Devonian, Ohio (109).
Great Basin: Brachiopoda, Silurian (128).
Gulf Coast: valvulinerian, Cretaceous (45).
Homolsomites: ammonite, Cretaceous (51).
homonymy: generic, pelecypod (127).
hydroids: Jurassic, Tethyan (50).
Ichnites: Triassic, Arizona and Utah (79).
Imitoceras: Devonian, Alberta (78).
index fossils: Silurian, Foraminifera, Kansas (68).
Indiana: cephalopod, Mississippian (108).
insectivore: Oligocene, Wyoming (49).
interambulacral columns: echinoids (57).
Iowa: cordaitean cones, Pennsylvanian (37).
Isocolidae: trilobite family (136).
Italy: fish, Triassic (1).
Japan: fauna and facies, Miocene (121).
Jurassic; geology of World (52); hydroids, Tethyan (50); Mollusca, Peru (22).
Kansas: footprints, Pennsylvanian (87); Foraminifera, Pennsylvanian (53); Foraminifera, Silurian (68).
Kentucky: nautiloid, Mississippian, (17).
Khmeria: Permian, Sicily (38).
Koenenites: Devonian, New York (131).
Lias: worm tube, England (4).
Litocephalus: trilobite, type species (77).
mammals: anthracotheres, Miocene and Oligocene, North America (64); Blancan, Nevada (63); Miocene, California (29); Miocene, Montana (28); Oligocene, Nebraska (48); Oligocene, Wyoming (49); Paleocene, Wyoming (40); Pleistocene, Nebraska (46); Pleistocene, Oklahoma (98); Pliocene, Nevada (62); Pliocene, South Dakota (42).
marine life: Baja California (32).
Maryland: cephalopods, Ordovician (33).

Maryvillia: revision of (83).
Michigan: Ostracoda, Mississippian (23).
microcrinoids: Mississippian, Oklahoma and New Mexico (106).
microfossils: staining (3).
micropaleontology: stereophotomicrography (60); text-book (71).
Microtus pennsylvanicus: mammal, Pleistocene, Nebraska (46).
Milleporidiidae: Jurassic, Tethyan (50).
Minnesota: Foraminifera, Ostracoda, and Radiolaria, Cretaceous (7).
Miocene: anthracotheres, North America (64).
Miocene: faunas and facies, Japan (121); Foraminifera and fish, California (80); Foraminifera, California (132); gastropod, California (141); Miocene, mammals, California (29); mammals, Montana (28); mylagaulid rodent (6); nonmarine Mollusca, Wyoming (86).
Mississippian: cephalopod, Indiana (108); microcrinoids, Oklahoma and New Mexico (106); nautiloid, Kentucky and Tennessee (17); new pelecypod, Cretaceous (102); Ostracoda, Fern Glen (30); Ostracoda, Michigan (23); tetracorals, California (118).
Modocia: Cambrian, Wyoming (91).
Mollusca: Jurassic, Peru (22); nonmarine, Miocene, Wyoming (86).
mollusks: Pleistocene zonation, Nebraska (36).
Montana: ammonite, Cretaceous (16); branchiopod, Devonian (139); fish, Cretaceous (138); mammals, Miocene (28).
morphology: echinoid (103).
nautiloids: Cretaceous and Tertiary, Australia (41); Ordovician, Virginia (123); *Pristeroceras*, Silurian (110); *Tylodiscoceras*, Mississippian, Kentucky and Tennessee (17).
Nebraska: mammal, Oligocene (48); mammals, Pleistocene (46); mollusk zonation in Pleistocene (36).
New Jersey: Ostracoda, Silurian (107).
New Mexico: microcrinoids, Mississippian (106).
New South Wales: productid brachiopods, Carboniferous (11).
New York: ammonoids, Devonian (131); cephalopod, Devonian (74); ostracodes, Devonian (96); Ostracoda, Devonian (105); Ostracoda, Silurian (107); *Receptaculites*, Devonian (130).
nomenclature: pelecypod (126).
North America: anthracotheres, Miocene and Oligocene (64); paleogeographic maps (58).
Nucinellidae: Eocene, Oregon (125).
Nevada: conodonts, Triassic (69); fusulinids, Pennsylvanian (124); fusulines, Permian (59); mammals, Blancan (63); mammals, Pliocene (62).
Odontopleuridae: type (134).
Oregon: cephalopod, Cretaceous (76).
Ohio: cephalopods, Devonian (109); conodonts, Devonian (104).
Oklahoma: mammals, Pleistocene (98); microcrinoids, Mississippian (106).
Oligocene: anthracotheres, North America (64); *Aturia*, Cuba (66) insectivore, Wyoming (49); mammal, Nebraska (48).
Ollenellidae: cephalic spines (44).
Ontario: gastropod, Devonian (142).
ontogeny: phacopid (114); septal development in tetracorals (14).
Ordovician: brachiopods, Tennessee (18); brachiopods, Virginia (143); cephalopods, Maryland (33); cephalopods, Texas (34); cephalopods, Virginia (123); sponges (95); trilobite, evolution (61).
Oregon: New Pelecypoda, Eocene (125).
Ostracoda: Cretaceous, Minnesota (7); Devonian, New York (96); Devonian, New York (105); mineralogy (97); Mississippian, Fern Glen (30); Mississippian, Michigan (23); new Tertiary, Florida (81); Silurian, New Jersey and New York (107); *Swartzochilina* new genus (88).
Otariidae: Miocene, California (29).
Paleocene: mammals, Wyoming (40).
paleoecology: Tertiary fish (24).
paleogeograpnic maps: North America (58).
paleontology: stratigraphical (113).
Paleozoic: coralline algae (54).
Parafusulina: Permian, Texas (9).
Paranacystis: echinoderm, Devonian, Brazil (13).
pelecypod: Cretaceous, Mississippi (102); generic homonymy (127); nomenclature (126); new Nucinellidae, Eocene, Oregon (125).
Pennsylvanian: cordaitean cones, Iowa (37); footprints, Kansas (87); Foraminifera, Kansas (53); fusulinid, Utah (116); fusulinids, Nevada (124); new brachiopods (19).
Permian: corals, Sicily (38); fusulines, Nevada (59); *Parafusulina*, Texas (9); Trachypsammiacea, coral (5).
Peru: Mollusca, Jurassic (22).
phacopid: odontopleurid protaspis (133); ontogenies (114).
photographing: small fossils (135).
Phyllocaridia: Cambrian, Utah (10).
Phylogeny: tetrapods (43).
pinniped: mammal, Miocene, California (29).

platyceratid: spinose, Devonian, Ontario (142).
Plectorthis plicatella minnesotensis: designation of type (129).
Pleistocene: mammals, Nebraska (46); mammals, Oklahoma (98); mollusk zonation, Nebraska (36).
Pliocene: Foraminifera, California (132); mammals, Nevada (62); mammals, South Dakota (42).
pollen: techniques (73).
Prioniodus: conodont genus (85).
Pristeroceras: restudy, Silurian (110).
Profusulinella: Pennsylvanian, Utah (116).
protaspis: odontopleurid (133).
Protista: discussion (35).
Protoscaphirhynchus squamosus: sturgeon, Cretaceous, Montana (138).
Pseudoarctolepis sharpi: phyllocaridia, Cambrian, Utah (10).
Pustulata: new Devonian brachiopod name (20).
quantitative studies: trilobites (92).
Radiolaria: Cretaceous, Minnesota (7).
Recent: barnacle identification (21).
Receptaculites: Devonian, New York (130).
Rhabdostichus: Devonian, Montana (139).
rodent: Miocene, mylagaulid (6).
Russia: Devonian Platform (56).
septal development: tetracorals (14).
Sicily: corals, Permian (38).
Silurian: Brachiopoda, Great Basin (128); cephalopod (110); eurypterid *Dolichopterus* (12); fenestellids (31); Foraminifera, Kansas (68); Ostracoda, New Jersey and New York (107).
South Africa: new brachiopod, Devonian (8).
South America: new brachiopod, Devonian (8).
South Dakota: mammals, Pliocene (42).
species: how many fossil (112).
Spinaptychus: Cretaceous, Texas (122).
sponges: Ordovician (95).
spores: techniques (73).
Stereophotomicrography: micropaleontology technique (60).
Stromatoporoidea: bibliography (39).
Swartzochilina: new ostracode (88).
Taxonomy: conodonts (70); echinoid (84); Prostista paradoxes (35); Tenrecoidea (49).
techniques: spores and pollen (73); staining microfossils (3); stereophotomicrography (60).
Tennessee: brachiopods, Ordovician (18); nautiloid, Mississippian (17).
Tenrecoidea: taxonomy (49).
teratoid foram: *Parafusulina*, Permian, Texas (9).
Tertiary: fish, California (24); Foraminifera, Ecuador (47); nautiloids, Australia (41); new ostracode, Florida (81).
Tethyan: hydroids, Jurassic (50).
tetracoral: Mississippian, California (118).
tetrapods: phylogeny (43).
Texas: cephalopod, Cretaceous (122); cephalopods, Ordovician (34); *Parafusulina*, Permian (9); trilobite revision, Cambro-Ordovician (140).
Thunnus: fish, Eocene, Caucasus (27).
tooth replacement: rodent, Miocene (6).
Tornoceras: Devonian, New York (74).
Trachyceras: Triassic, western United States (93).
Trachypsammia: Permian, Sicily (38).
Trachypsammiacea: Permian coral (5).
Triassic: cephalopod, Western United States (93); conodonts, Nevada (69); fish, New York (1) Ichnites, Arizona and Utah (79).
Trilobita: lichid protaspis and *Acanthopyge consanguinea* (137); Odontopleuridae type (134); *Acrocephalites? glomeratus*, Cambrian, Wyoming (89); *Aphelaspis*, Cambrian, Wyoming (90); Cambrian and Ordovician, evolution (61); Cambrian, Wyoming (25); Isocolidae (136); *Litocephalus*, type (77); *Maryvillia*, revision (83); *Modocia*, Cambrian, Wyoming (91); odontopleurid protaspis is phacopid (133); olenellids (44); quantitative studies (92); revisions, Cambro-Ordovician, Texas (140).
Tylodiscoceras: nautiloid, Mississippian, Kentucky and Tennessee (17).
type species: *Litocephalus* (77).
Utah: fusulinid, Pennsylvanian (106); Ichnites, Triassic (79); Phyllocaridia, Cambrian (10).
valvulinerian: Cretaceous, Gulf Coast (45).
vertebrate: mammals, Pliocene, South Dakota (42); phylogeny of tetrapods (43).
Virginia: brachiopods, Ordovician (143); cephalopods, Ordovician (123).
Western United States: trilobite, Triassic (93).
worm tube: Lias, England (4).
Wyoming: insectivore, Oligocene (49); mammals, Paleocene (40); non-marine Mollusca, Miocene (86); trilobites, Cambrian (25, 89, 90, 91).

SPECIAL PUBLICATION NO. 5 OF
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
Box 979, Tulsa 1, Oklahoma

REGIONAL ASPECTS OF CARBONATE DEPOSITION—A Symposium with Discussions. Presented at the St. Louis meeting, 1954; edited by R. J. LeBlanc and Julia G. Breeding. Papers include: "Distribution of Marine Carbonate Sediments," by John Rodgers; "Geological Studies on the Great Bahama Bank," by Norman D. Newell and J. Keith Rigby; "Early Diagenesis and Lithification of Shallow-Water Carbonate Sediments in South Florida," by Robert N. Ginsburg; "Mississippian Carbonate Deposits of the Ozark Region," by Raymond C. Moore; and "The Dolomite Problem," by Rhodes W. Fairbridge. Paper bound. Approximately 200 pages with 22 full tone illustrations.

PRICE TO AAPG AND SEPM MEMBERS.....$3.50

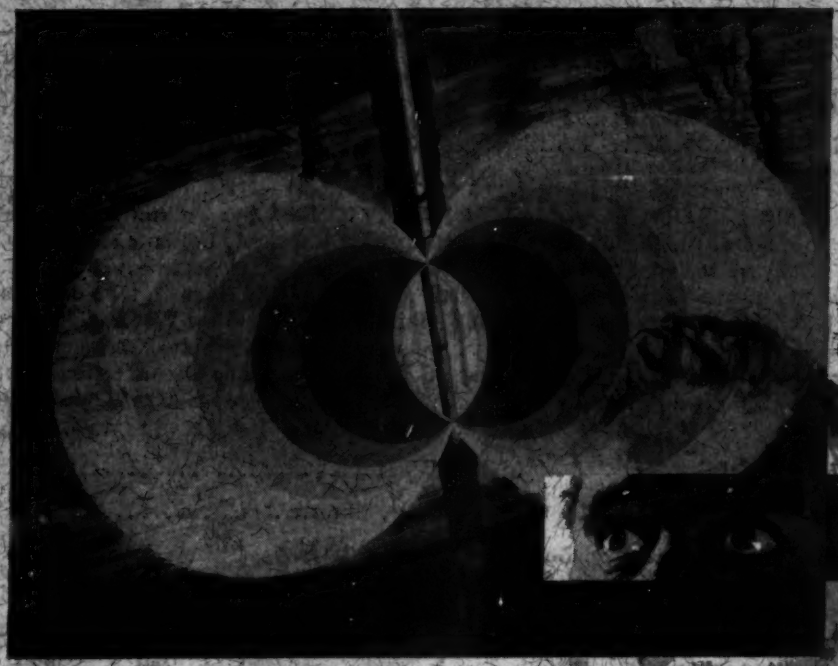
PRICE TO NON-MEMBERS (oil companies, libraries, etc.).....$4.50

Payments are being accepted now. Book will be mailed later.

TREATISE ON INVERTEBRATE PALEONTOLOGY

The following parts of the TREATISE ON INVERTEBRATE PALEONTOLOGY are available as cloth-bound volumes from: The Geological Society of America, 419 West 117th Street, New York 27, N.Y.

Part D: PROTISTA $3.00
Part E: ARCHAEOCYATHA AND PORIFERA $3.00
Part F: COELENTERATA $7.00
Part G: BRYOZOA $3.00
Part P: CHELICERATA $3.50
Part V: GRAPTOLITHINA $3.00



sees more—tells more

ANOTHER NEW SERVICE DEVELOPED BY SCHLUMBERGER —THE COMBINATION INDUCTION-ELECTRICAL LOG

This new service incorporates advantages given only by the Induction Log while retaining important features of the Electrical Log.

The Induction Log . . .

- has none of the lags, shadow zones and reflection peaks associated with the long normal and lateral curves
- gives more detail on thin beds
- is less influenced by the mud column
- is less influenced by the invaded zone
- gives greater accuracy in low resistivities and in true resistivity determinations
- provides more accurate determination of oil water contacts

This New Service Combines These Curves:

Electrical Log
Spontaneous Potential
16" Short Normal
16" Amplified Normal

Induction Log
40" Resistivity
40" Conductivity

The combination is a more easily used log for quick analysis or detailed study — and with fewer resistivity spacings.

SCHLUMBERGER WELL SURVEYING CORPORATION — THE EYES OF THE OIL INDUSTRY